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ON THE CORROSION OF BOILER TUBES IN THE U. S. NAVY.

BY WALTER F. WORTHINGTON, LIEUT. COMMANDER, U. S. N.

[Continued.]

Referring to the subject of corrosion of boiler tubes in the JOURNAL OF THE AMERICAN SOCIETY OF NAVAL ENGINEERS, Vol. XIII, No. 2, page 336, it was stated that from the engineer's point of view the most pressing need is to discover what can be done to stop or check corrosion.

Several of the authors quoted in Vol. XII, No. 3, page 602, state that iron and steel can be prevented from rusting by submerging them in an alkaline solution. The statement itself is rather vague, and the writer has not been able to discover any satisfactory demonstration of its truth by means of careful experiments of sufficiently long duration. Pure fresh water alone, without alkali, is a preservative from rust under certain conditions, and at times iron and steel of various compositions, as well as copper and bronze, are found to have a very long life compared with other samples which appear to be subject to the same

conditions. It is essential that the same pieces should be subjected to conditions known to be the same and known to produce rust, and then show what single change in the conditions will prevent rust.

With this end in view the test pieces referred to in the JOURNAL, Vol. XIII, No. 2, were carefully weighed and replaced in the tank. The slight discrepancies in the weights given in the following table compared with the weights given in table V, page 334, Vol. XIII, No. 2, of the JOURNAL, are undoubtedly due to slight inaccuracies in weighing and to small flakes of rust having been knocked off in handling since last weighing. The tank was filled with seven gallons of distilled water rendered alkaline by the addition of 124 grammes of carbonate of soda (sal soda). The stream of air was then turned on, the pieces shifted each week, as before, and the water tested each week with litmus paper and found to give an alkaline reaction. At the end of five weeks, the amount of water having been reduced by evaporation, it was necessary to add 2 gallons of distilled water and 31 grammes of carbonate of soda. Six weeks later another addition of 2 gallons of water and 62 grammes of carbonate of soda was made to keep the tank filled and the water alkaline. During the course of these sixteen weeks it was noticed that the white bottom of the porcelain-lined tank remained remarkably clear, there being not enough oxide to cover it, while during the previous three sets of tests, the precipitate of rust on the bottom of the tank was from 1½ to 2 inches deep. Also when the pieces were last taken out and washed there was hardly rust enough adhering to them to discolor the washing water. At the end of sixteen weeks, when each piece had been in every possible position, all were taken out, washed and carefully weighed and photographed. The weights are given in the table on opposite page.

It will be seen that No. 4 has lost 2 grammes but no other piece has lost a single gramme in weight. Ten pieces show an increase of half a gramme, due probably to a slight amount of rust forming and clinging to the metal. By comparing the photographs taken at the conclusion of this set of experiments with those taken at the conclusion of the previous set it will be

seen that there has been no appreciable change in the appearance of the surfaces.

TABLE VI.

No.	Kind of material.	Total area.	Weight at beginning of 4th sixteen weeks.	Weight at end of 4th sixteen weeks.	Total loss of weight during 4th 16 weeks.	Remarks.
		Sq in.	*Gram.*	*Gram.*	*Gram.*	
1	Nickel-steel	55.40	247	247	0	Bent hot.
2	Nickel-steel	56.40	250	250	0	Bent cold.
3	Solid cold drawn O. H.	40.88	368	368	0	Samples from 1 tube.
4	Solid cold drawn O. H.	43.18	376	374	2	
5	Solid cold drawn O. H.	53.62	493	493½	.....	Samples from 1 tube.
6	Solid cold drawn O. H.	48.36	450	450½	.....	
7	Solid cold drawn O. H.	56.57	409	409½	.....	Samples from 1 tube.
8	Solid cold drawn O. H.	57	448	448½	.....	
9	Lap-welded Bessemer	57	425	425½	.....	All from 1 maker.
10	Lap-welded Bessemer	57	438	438½	.....	
11	Lap-welded Bessemer	57	476	476½	.....	
12	Lap-welded Bessemer	57	431	431½	.....	
13	Lap-welded iron	51.72	401	401	.....	All from 1 maker.
14	Lap-welded iron	55.83	420	420½	.....	
15	Lap-welded iron	56.24	426	426	.....	
16	Lap-welded iron	57	444	444½	.....	

These experiments throw light on several points:

They show that when a boiler is not in use corrosion can be stopped entirely by keeping the boiler full of fresh water rendered alkaline by sal soda.

Most writers on the care and preservation of boilers direct that soda be put in when the water is found to be acid. This advice is misleading, for the obvious inference is that soda need not be put in if the water is not found to be acid to litmus.

The experiments show that soda acts to prevent such corrosion due to the presence of air in the water, and, therefore, a sufficient quantity should always be present.

As stated in Vol. XII of the JOURNAL, it is not likely that our boiler tubes have been injured from the water being allowed to get acid. Doubtless, however, they have been injured by air, the presence of which could not be detected by litmus paper, the

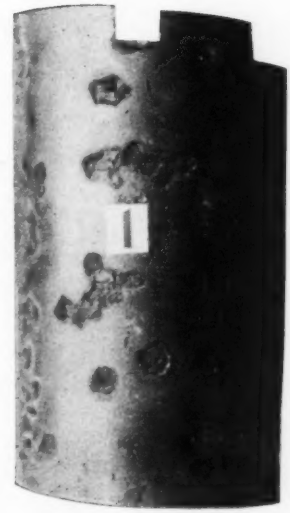
means prescribed by the Naval Regulations for determining the necessity for the use of soda.

Although the experiments cover only the case of corrosion in cold water, soda will also have the same effect in hot water. If future experiments show this to be the fact it will be of great advantage to all engineers, especially to those who now use milk of lime to form a coating of scale, thereby diminishing the efficiency of their heating surface while the scale remains intact and localizing the corrosion when the scale peels off in places. On naval vessels it is practically impossible to keep on hand a supply of the unslaked lime necessary to form such scale, owing to the limited stowage room in suitable places, to the fact that ships are often absent for many months from a base of supplies, and unslaked lime becomes "air slaked" when kept long.

With regard to the amount of soda necessary and to its effect in causing the boilers to foam, there are several points to be noted.

In the above experiments the attempt was made to keep down the quantity of sal soda to the least amount which could be detected with litmus paper. The 217 grammes used with 11 gallons of water stopped corrosion absolutely in 15 cases and practically stopped it in the other case, although the supply of air was excessive and far greater than it ever would be in a boiler in use, especially if part of the air was liberated in the feed tank by keeping up its temperature and if no air was allowed to be drawn in through the intermittent action of the feed pump. The amount of soda should evidently be proportional to the amount of air which enters the boiler. This will vary with the amount of feed water. If for a given service a water-tube boiler holding five tons is used, it will require as much soda as a Scotch boiler for the same service holding twenty tons of water, the weight of feed water depending on the weight of water evaporated together with the weight which escapes through leakage, and not on the weight which the boiler holds. A leaky boiler will require more than one that is tight, both because it will require more feed water to furnish the same weight of steam and also because some of the soda solution will leak out.

The amount used in the experiments, 217 grammes to 11 gal-



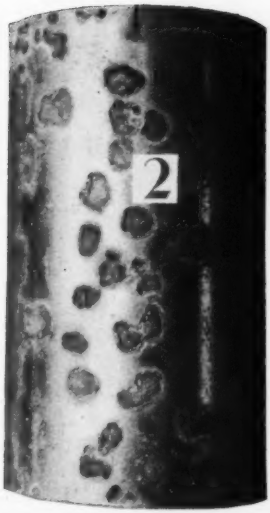


FIG. 1.

FIG 2.

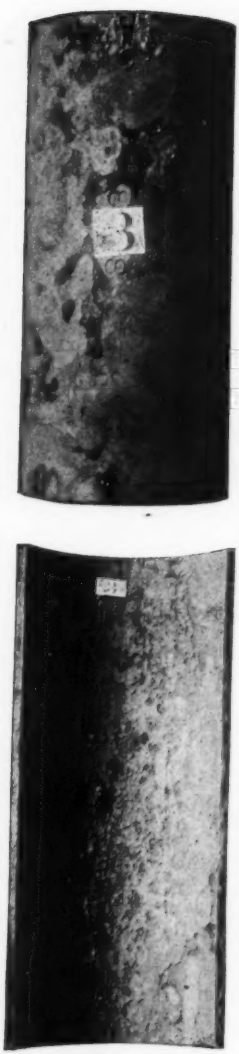


FIG. 3.

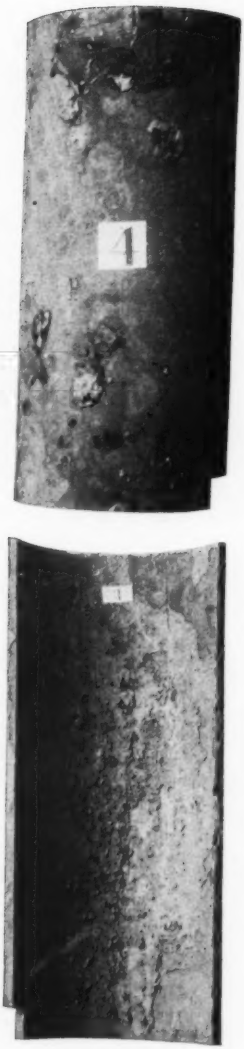


FIG. 4.

Fig. 5.

Fig. 6.

FIG. 7.

FIG. 8.

Fig. 9.

Fig. 10.

FIG. 11.

FIG. 12.

FIG. 13.

FIG. 14.

FIG. 15.

FIG. 16.

lons of water (about 200 pounds per ton of make-up feed), is evidently far in excess of what would be required on shipboard, and would of course be impracticable except for boilers not in use. The main purpose of the experiments was simply to ascertain whether or not sal soda would arrest the corrosion caused by air.

In practice the writer has found that if 7 pounds of sal soda are put in a Scotch boiler holding 20 tons of water and used to its full capacity with constant feed at a temperature of 125 degrees Fahrenheit for three weeks the water will remain alkaline to litmus for that length of time. The exact amount required in any case can easily be determined by making weekly tests for alkalinity. As long as the alkali remains it must be effective.

As to the amount which can be used without causing foaming, this depends upon the tendency of the particular boiler to foam and upon the way the soda is put in, whether all at once or at intervals. Unfortunately, figures are lacking, but some facts may be cited in illustration.

In the early days of steam navigation, when jet condensers were used, it was well known that the low-pressure boilers would foam when the vessel steamed out of a fresh-water river into the sea, or *vice versa*, changing the feed water suddenly from fresh to salt or the reverse. A similar action appears to take place in the case of using soda. If the boiler has a tendency to foam a sudden addition of soda in the feed tank may start foaming, or if an excessive quantity of soda is put into a boiler at one time it will foam. The writer was told by the chief engineer of a merchant steamer that he had on one occasion been directed by the owners to put 100 pounds of soda at one time into a Scotch boiler developing at full power about 1,250 I.H.P., and as a consequence he hardly got a sight of the water in the gage glass during the voyage. Later he changed the practice, and used soda at the rate of 5 pounds per day during the voyage without further trouble.

The chief engineer of one of our battleships stated that he sometimes had the water in the boilers so strongly alkaline that it would burn the tongue when tasted, and yet there was never any trouble from foaming.

The writer has used large quantities of soda until incrustations appeared above the gage cocks and other fittings of locomotive marine boilers without experiencing any difficulty from foaming.

All of these instances show that it is quite practicable to use soda in moderate quantities.

Owing to the unavoidable absence of the writer from the country, these experiments on the corrosion of boiler tubes will have to be discontinued, although several interesting fields of inquiry open up. It would be desirable for some one to extend these researches, first to demonstrate whether or not sal soda will stop the corrosion of tubes in fresh water of the temperature corresponding to a pressure of 200 to 250 pounds; then determine the least amount of soda, or other alkali, which will answer the purpose, using a chemical test more delicate than litmus paper to test for alkalinity at the beginning and end of the experiment to discover at what rate the soda disappears when the amount of air admitted is maintained in excess at all times. It would also be interesting to try other alkalies to see if these are any more efficacious than soda and at the same time cheap enough to be used commercially.

In conclusion, the writer desires to express his appreciation of the unremitting and zealous attention with which the details of the foregoing experiments have been carried out by Mr. F. N. Burrows of Pittsburg, Pa., who kindly volunteered in the absence of the writer to look after this work which has been going on for nearly two years. The data collected speaks for itself; the correspondence between the various results and their freedom from unaccountable anomalies is convincing evidence that the facts were recorded exactly as found and no attempt made to either prove or disprove a preconceived theory.

REVIEW OF MARINE ENGINEERING DURING THE LAST TEN YEARS.

By Mr. James McKechnie, of Barrow-in-Furness.

[Condensed from a paper read at the Barrow-in-Furness meeting of the Institution of Mechanical Engineers.]

The choice of the subject of this paper is due to the fact that at the beginning of each of the three past decades a paper has been contributed to the Institution reviewing the progress of marine engineering. At the Liverpool meeting in 1872, Mr.—now Sir—Frederick Bramwell, past president, gave some characteristically racy reminiscences; at the Newcastle meeting in 1881, Mr. Frank C. Marshall, who has done so much for the advancement of marine engineering, continued the records of development; and again at the Liverpool meeting in 1891, a similar decennial review was made by my friend and predecessor, Mr. Alfred Blechynden, whose early death in 1897 terminated prematurely a brilliant career. A similar review is appropriate now at the beginning of a new century, when there is a general tendency to erect mile stones marking the stages reached in each branch of science. As to the selection of author, the responsibility is the president's, and he was doubtless influenced solely by the fact that this year's summer meeting is being held at Barrow-in-Furness.

Fuel Economy.—As the engineer cannot ignore the dictates of finance, progress must primarily be measured from the standpoint of economy. A steamship is built to carry a given load of passengers or of material for a given distance; and success is reckoned according to the expense incurred in doing this work. The engineer's part is considerable, and is largely associated with fuel economy and repairs, as well as with first cost. It can scarcely be said that the development during the past decade

has been so marked, so far as fuel economy is concerned, as that in immediately preceding decennial periods; largely because each successive attainment necessarily involves relatively greater effort. In 1872 the coal consumption was recorded as 2.11 pounds per unit of power per hour; by 1881 it had been brought down to 1.83 pounds; in 1891, when the triple-expansion engine had come into almost universal use, the rate became 1.52 pounds; and now a careful analysis shows that the average for new ships with the latest equipment is about 1.48 pounds.

TABLE I.—AVERAGE RESULTS OF MARINE ENGINES, 1872, 1881, 1891, 1901.

Boilers, engines and coal.	Average results.			
	1872.	1881.	1891.	1901.
Boiler pressure, pounds per square inch...	52.4	77.4	158.5	197
Heating surface per square foot of grate, square feet.....	...	30.4	31	38 and 43*
Heating surface per indicated horse-power, square feet.....	4.41	3.917	3.275	3
Coal per square foot of grate, pounds.....	...	13.8	15	18 and 28*
Revolutions per minute.....	55.67	59.76	63.75	87
Piston speed, feet per minute.....	376	467	529	654
Coal per indicated horsepower per hour, pounds	2.11	1.83	1.52	1.48
Average consumption on prolonged sea voyage, pounds.....	...	2	1.75	1.55

* Natural and forced draft respectively.

In determining coal consumption, actual performances at sea should be taken rather than trial trip results, as seems to have been the case in preceding papers; and thus the coal consumption of 1881, instead of being 1.8 pounds, should rather be 2 pounds, or 2.1 pounds, for, as shown in Table IV, the mean consumption of twelve steamers built in 1878–80, and fitted with compound engines, on voyages aggregating 340,000 miles, works out to 2.1 pounds per horsepower per hour. Again, the coal consumption of 1891 was given as 1.52 pounds; but the sea records of ships built then show a consumption of between 1.75 pounds and 1.8 pounds, as recorded in Table III, giving a comparison of performances between Liverpool and Grand Canary, voyages which occupy about a week, and represent each from

1,400 to 1,700 miles steaming. Some little allowance, however, should be made in this case for the coal used for pantry and heating purposes during the voyages. Thus it may be said that in 1881 the average consumption at sea was 2 pounds per horsepower hour; in 1891 1.75 pounds, and now about 1.55 pounds (see Table II). Upon the sea performance the saving to-day is about $\frac{1}{5}$ pound per horsepower per hour as compared with ten years ago; and about $\frac{1}{2}$ pound as compared with twenty years ago; a result which is the more satisfactory when it is borne in mind that it has been attained without multiplying the working parts of the engine, or so increasing the delicacy of the machinery as to involve a higher skilled labor in its management on shipboard.

TABLE II.—MEAN RESULTS FROM ENGINEER'S LOG OF CUNARD STEAMERS, 1899–1900.

Name of Vessel.	Voyage.	Speed in knots.	Indicated horsepower.	Revolutions per minute.	Stroke in inches.	Piston speed in feet per minute.	Coal Consumption.	
							Tons per day.	Pounds per indicated horsepower per hour.
S.S. *Saxonia*.....	Liverpool to Boston	14.5	10,078	76	54	684	138	1.28
	Boston to Liverpool	15	10,230	77	54	693	136	1.24
S.S. *Ultonia*.....	Liverpool to Boston	11.5	3,997	69	48	552	66	1.54
	Boston to Liverpool	11.8	4,292	71	48	562	62	1.35

The coal consumption given is for the propelling machinery, and does not include that used for refrigerating or galley purposes or port use, and is therefore the actual amount of coal used at sea under ordinary conditions. The mean consumption for the *Saxonia* = 1.26 pounds; for the *Ultonia* = 1.445 pounds.

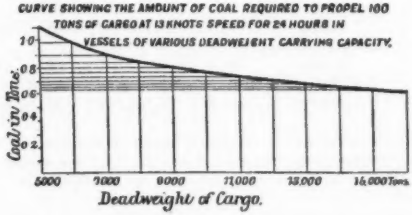
The *Saxonia* has a cargo capacity of 10,400 tons deadweight, and 19,808 tons measurement of cargo to shelter deck, leaving the promenade and bridge deck for first and second-class passengers. The *Ultonia* carries 11,290 tons deadweight and 20,000 tons measurement to the shelter deck, which leaves the bridge deck clear for passengers.

The increased economy is partly due to the higher steam pressure now in use. In 1891 the average was about double that of 1881, and now the increase is from 158 pounds to 197 pounds

per square inch, the average for forty-five ships with triple-expansion engines built within the past nine months being 180 pounds, and for nine steamers with quadruple-expansion engines 214 pounds. In former years naval machinery was included in the reckoning, the conditions being similar to those obtaining in the merchant service; but now, with the adoption of water-tube boilers, the practice is dissimilar, and naval ships are not considered in determining this year's averages. As a result of the higher steam pressure and more economical engines, more power is obtained from the boilers per square foot of heating surface, the average per indicated horsepower having in ten years decreased from 3.275 to 3 square feet. At the same time the piston speeds of engines have considerably increased. The average ten years ago, even including warships, has now become the mean rate for the tramp steamer—530 feet per minute, while many steamers for high speed attain to 880 feet, a few to 950 feet.

Economy per 100 Ton-Miles of Large Cargo Carriers.—Improved economy in the oversea transport of commerce is also being sought for now in the greater size of cargo steamers, the fuel consumption of which does not increase in the same ratio as the cargo capacity. This point is illustrated in the diagram, Fig. 1, which shows the coal consumption per twenty-four hours for

Fig. 1.



each 100 tons of deadweight carried in vessels of progressive size, each steaming 13 knots. The particulars of the various ships upon whose performances this diagram has been based are set out in Table V. It will be seen in the first place that the displacement of the ship itself does not increase in quite the same

proportion as the deadweight carried, the immersed midship area increases at a slower rate than the load displacement, and the power necessary for a given speed advances at a correspondingly lower ratio. Thus, a ship to carry only 5,000 tons requires machinery of 3,475 indicated horsepower to propel her at 13 knots; while in the case of a ship of treble the capacity the power is scarcely double. In other words, the consumption of coal per hundred ton-miles in a now relatively small ship, taking 5,000 tons of cargo, is 8 pounds, while the vessel taking 16,000 tons uses only 4.4 pounds per 100 ton-miles, the rate of consumption per unit of power per hour being assumed in all cases at 1.5 pounds. Not only is the fuel consumption per ton carried less, but the first cost per ton carried need not be greater, and the working expenses per ton generally are lower, because mechanical means are introduced more freely for many purposes, while the *personnel* does not increase *pro rata* with size.

This greater economy is the cause of the steady growth in the size of ships, and Table VI is therefore instructive as indicating the size of vessels launched in the United Kingdom in each year since 1892. It needs no comment. The total number of vessels of over 10,000 tons in existence 10 years ago was two; now there are fifty-one, of which ten are over 13,000 tons. Ten years ago there were only ninety one vessels which exceeded 5,000 tons register; at the end of last year there were 505. The distribution of these vessels in point of tonnage and of nationality is recorded on Table VII, showing that the higher economy of the larger ships is being widely recognized. Germany, it will be noticed, maintains her position with Britian so far as large ships are concerned. But these are questions of general policy; details as to the problems involved in the attainment of economy are of more importance.

Steam Pressures and Boiler-Testing Standards.—The author naturally begins with steam generation, and it will no doubt conduce to the general harmony if the subject of the water-tube boiler is not dealt with. It would demand too much time; the question is more or less *sub judice*, and its consideration in any case would involve a protracted discussion, perhaps without

direct value, as there are very few engineers who can boast that they have not taken out a patent for a water-tube boiler. There is enough in connection with cylindrical boilers as well as with machinery practice generally upon which a free expression of opinion is desirable. There has come within the past ten years some uniform degree of practice as regards cylindrical boilers. There is generally a preference for the single-ended type, although convenience often requires the adoption of the double-ended boiler; but the through combustion chamber has, generally speaking, become a thing of the past. It has already been pointed out that the pressure for forty-five ships fitted with triple-expansion engines within the past nine months averages 180 pounds, while in the case of nine steamers with quadruple-expansion engines it averages 214 pounds, the maximum attained with cylindrical boilers for merchant practice being 267 pounds. In the naval service steam pressures of 300 pounds are now quite common with water-tube boilers. There is thus an increase on the average in merchant steamers of about 25 per cent., and in naval practice of 100 per cent., as compared with ten years ago.

It would seem as if the limit was being reached with tank boilers, because in the case of the boiler to work at 267 pounds the shell plates are $1\frac{9}{32}$ inches thick, although the diameter is only 13 feet. Ten years ago there was a strong desire that the Board of Trade and Lloyd's might reconsider the ratio of test pressure to the working pressure, but it still continues to be double. The Board of Trade have accepted shell plates having a tensile strength of 29 to 32 tons per square inch, but the margin here between maximum and minimum is very small, and each plate must be tested by the surveyor. The material test is the same as ten years ago, *i.e.*, from 27 to 32 tons. Prior to the adoption of the water-tube boiler, the Admiralty practice was to test the boiler up to 90 pounds over the prospective working pressure, and in this case the test pressures for a boiler designed for 190 pounds working pressure would be 280 pounds instead of the Board of Trade standard of 380 pounds. Advantage could thus be secured in decreased scantlings. The relative

stresses, factors of safety and tensile strength of material are as follows :

Stress on Steel Stays in Steam Space.

Board of Trade,	9,000 pounds at working pressure.
" "	18,000 pounds at test.
Admiralty,	10,400 pounds at working pressure.
"	18,000 pounds at test.

Factor for Shells.

Board of Trade, ...	4.5
Admiralty, ...	3.9

TENSILE STRENGTH OF MATERIAL.

Board of Trade, 29 to 32 tons per square inch with a minimum elongation of 18 per cent. in 10 inches.

Admiralty, 27 to 30 tons per square inch with a minimum elongation of 20 per cent. in 8 inches.

It will thus be seen that for a given diameter there is, with the Admiralty rule, a possible saving in weight, or alternatively the diameter within reasonable limits of prudence may be increased, regard being had to the thickness of shell plating that may be deemed practicable. At the same time, it is a matter for consideration whether the differences in the rules as to boiler scantlings enforced by government departments and underwriting associations should not be carefully examined with the view of determining some uniform standard, for while in the case of the Bureau Veritas the pressure permissible for given conditions is 5 per cent. less than with Lloyd's, the United States Board of Survey permits of about 20 per cent. higher pressures.

Boiler Draft and Evaporation.—Except in war vessels the closed-stokehold system is seldom resorted to now, the preference in the merchant service being in favor of heating the air supply before it reaches the furnace, either by a closed ash-pit forced system, as in the Howden arrangement, or with an induced draft. In both cases heat is got from the waste gases. The horsepower of ships fitted with the first-mentioned heated-draft

TABLE III.—SEA VOYAGE PERFORMANCES OF STEAMERS BUILT 1889-1893

(Particulars supplied by the British and African Steam Navigation Company, Limited.)

No. of voyage.	Ports and dates.	Steaming time.	Distance run.	Total revolutions.	Revolutions per minute.	Speed. By screw.	Speed. By ship.	Slip, per cent.	Mean draught of ship.	Average displacement.	Average deadweight.	Average I.H.P.	Coal per day.	Kind of coal and report on quality.	Coal per I.H.P.	Weather—adverse.
		d. h. m.				*knots.*	*knots.*		*ft. in.*	*tons.*	*tons.*		*tons cwt.*			
							S. S. *BOMA.* Built 1889.									
11	Liverpool to Teneriffe. Oct., 1893.	7 13 0	1660	608,430	56.0	9.67	9.16	5.3	17 1½	4264	2486	950	16 11	South Wales—fair.	1.62	1 day strong head, 6 days light head.
29	Liverpool to Teneriffe. Feb., 1898.	6 22 45	1660	602,760	60.2	10.39	9.95	4.2	18 6	4673	2895	1110	21 19	North Wales—swift and dirty.	1.84	3 days moderate head, 1 day light head.
33	Liverpool to Teneriffe. May, 1899.	6 22 0	1660	599,210	60.1	10.37	10.00	3.5	19 9	5047	3269	1160	23 2	North Wales—quick burning.	1.90	3 days strong following.
39	Liverpool to Madeira. Feb., 1901.	6 9 0	1440	511,960	55 7	9.61	9.41	2.0*	19 3	4897	3119	1100	22 12	45 per ct. Lancashire (quick burning) 55 per cent. N. Wales (quick burning)	1 90	1 day heavy following sea.*
							S. S. *LOANDA.* Built 1891.									
9	Liverpool to Madeira. Sept., 1893.	5 23 30	1440	536,010	62.2	10.20	10.03	1.6	16 7½	4686	2726	870	15 15	South Wales—very good.	1.69	1 day strong head.
10	Liverpool to Madeira. Dec., 1893.	6 6 17	1440	554,680	61.5	10.08	9.58	4.9	18 8½	5352	3389	860	16 16	20 per cent. N. Wales—good. 80 per cent. S. Wales—good.	1.72	Fair weather.
12	Liverpool to Grand Canary. July, 1894.	7 3 0	1660	611,950	59.6	9.78	9.70	0.8	16 10	4756	2703	780	16 14	North Wales—good.	1.99	Fair weather.
36	Liverpool to Grand Canary *via* Madeira. June, 1900.	7 10 15	1700	660,350	61.7	10.11	9 53	5.73	17 3	4888	2925	860	17 11	North Wales—mixed quality.	1.90	2 days light head.
							S. S. *BATANGA.* Built 1893.									
2	Liverpool to Grand Canary. March, 1894.	6 20 0	1660	640,840	65.1	10.67	10.12	5.1	16 4	4679	2549	950	18 13	23 per cent. N. Wales—fair. 77 per cent. S. Wales—fair.	1.83	
6	Liverpool to Grand Canary. *via* Teneriffe. March, 1895.	6 22 50	1700	643,670	64.3	10.54	10.18	3.4	16 9	4810	2680	950	19 0	North Wales—swift.	1 87	
11	Liverpool to Grand Canary. June, 1896.	6 14 30	1660	624,020	65.6	10.75	10.47	2.6	16 3	4653	2523	990	21 1	North Wales—quick burning.	1.96	Fair weather.
28	Liverpool to Grand Canary *via* Madeira. July, 1900.	7 1 30	1790	675,900	66.4	10.89	10.03	7.9	17 11	5180	3050	1050	21 14	North Wales—fast.	1 90	2 days light head.

* Previous to voyage No. 39 the ship was fitted with spare propeller having 77 square feet of surface. Voyages 14, 29 and 33 were made with a propeller of 70 square feet surface.

Consumption of coal per day as given includes consumption for steering engines, winches, pantry heating purposes, etc., during the steaming time, and also includes centrifugal circulating pump, and for dynamo in the two latter class steamers.

system is 3,406,000 indicated horsepower, and there can be no doubt that very economical results have been achieved. This is the system adopted in both the Cunard ships whose results are set out in Table II, and it will be seen that in the later vessel, the *Saxonia*, the mean consumption per indicated horsepower per hour is only 1.26 pounds during the round transatlantic voyage; while in the case of the Clan Line return, Table IV, the mean of seventeen voyages made by twelve steamers is 1.39 pounds, an eminently satisfactory result. With this system of draft it is possible to burn more coal per square foot of grate and to obtain a higher evaporation per square foot of heating surface. The average ratio of heating surface to grate area in the case of thirty forced-draft steamers built within the last nine months is 39 29. Two or three of the vessels were designed for particular trades and special fuel, for which large grates are needed; but taking ordinary steamers, the ratio probably averages 42 to 43 square feet for forced draft, while with natural draft the average, also for thirty steamers, is 38.3. Ten years ago the mean for twenty-eight steamers was 31 square feet, and twenty years ago the mean of thirty-nine steamers was 30.43 square feet; so that it will be seen that the modern cylindrical boiler has 30 per cent. more heating surface per square foot of grate. The coal burned per square foot of grate per hour in 1881 was 13.80 pounds, and in 1891 15 pounds; it now averages with natural draft 18 pounds, and with forced draft as high as 28 pounds. Finally, the heating surface allowed per unit of power is 3 square feet, as compared with 3.275 ten years ago and 3.91 twenty years ago. The increase in steam pressure and other changes has enabled the power per ton of boiler to be considerably increased, 16.5 indicated horsepower per ton, including fittings, now being attainable in cargo steamers, 20 indicated horsepower in passenger steamers, 30 indicated horsepower in high-speed channel steamers, and 23 indicated horsepower in Atlantic liners.

Oil Fuel.—It can scarcely be said that much progress has been made in the general application of oil fuel, although it confers great advantages in uniform and easily regulated stoking. Nearly all oil-tank steamers now use liquid fuel, but few general

TABLE IV.—PERFORMANCES OF MERCHANT STEAMERS; FIRST WITH COMPOUND ENGINES, AND SUBSEQUENTLY WITH TRIPLE-EXPANSION ENGINES, TO ILLUSTRATE IMPROVED ECONOMY.

(Particulars supplied by Messrs. Cayzer, Irvine and Co.)

Class and date.	Description.	Length of each voyage in knots.	Ship.			Deadweight.	Engines, diameter of cylinders.	Working pressure.	Indicated horsepower (mean).	Speed (mean).	Coal consumption.		Knots per ton of coal.	System of draft
			Length.	Breadth.	Depth.		Stroke.				Tons per day.	Pounds per I.H.P. per hour.		
			feet.	*feet.*	*feet.*	*tons.*	*inches.*	*lbs.*		*knots.*	*tons.*	*lbs.*		
"A" 1878	Results from six steamers with compound engines. (Means of seven voyages.)	20,416	305	34.85	24 25	3,000	$\left\{\frac{34-63}{42}\right\}$	80	700	8.2	16.5	2.2	12.0	Natural.
"A"	Results from same steamers with triple-expansion engines. (Means of seven voyages.)	20,504	305	34.85	24.25	3,000	$\left\{\frac{22-34-59}{42}\right\}$	160	1,000	9.5	15 0	1.4	14.8	Howden's forced.
"B" 1880	Results from six steamers with compound engines. (Means of ten voyages.)	20,973	330	40.2	26.3	4,200	$\left\{\frac{39-75}{48}\right\}$	85	1,230	9.45	27.17	2.06	8.33	Natural.
"B"	Results from same steamers with triple-expansion engines. (Means of ten voyages.)	20,478	330	40.2	26.3	4,200	$\left\{\frac{24\,5-40-67}{48}\right\}$	180	1,650	10 4	24.25	1.37	10.2	Howden's forced.

traders have adopted the system. The disadvantage of greater cost of oil is diminishing, owing to the increasing price of coal and a more plentiful supply of oil; but apart from this, there is the slightly greater prime cost of the ship, with its more carefully built bunkers to store the oil fuel. In the construction of a petroleum steamer all bulkheads require to be oil-tight, and no difficulty is therefore experienced in making the bunkers similarly tight. Even if the oil were carried in the double-bottom and water-ballast tanks, it is estimated that the care in construction and difference in structure adds £2,000 to the cost of a moderate-size ship. Oil, when water-charged, involves difficulties, although separators may partly overcome these. Such objections are not insuperable, and, moreover, a high degree of perfection has been attained in burner appliances; but there is still wide difference of opinion as to whether the mechanical spray, the steam or air-propelled jet, or the volatilized system proves most efficient. The first requires brick lining to maintain the initial furnace temperature; the steam spray involves a loss of fresh water, which has to be made up by the evaporators, and the fuel thus used is equal to from 2 cwt. to 3 cwt. per day in a 1,000-horsepower ship; with air the steam for working the compressors also involves fuel consumption, but the quantity is less than that necessary for making up the water lost by the steam spray. The boiler evaporation is probably from 12 pounds to 15 pounds of water from and at 212 degrees per pound of oil fuel, and even more is claimed in some cases. The use of volatilized oil seems to offer great advantages; it is vaporized by being first heated and subsequently distilled in the presence of superheated steam within a retort burner, and in this case the evaporation is probably slightly higher, without any initial heat expenditure of great extent. But, after all, it seems still a question of the relative price of coal and oil, so far, at least, as slow steaming is concerned. In naval practice difficulties have been experienced in securing the same amount of steam with oil fuel from water-tube boilers as is commonly obtained with coal. On a three hours' trial as much as 90 pounds of coal has been burned per square foot of grate per hour, and it has thus far

been found impossible to approach this result economically with oil fuel. In fact, the maximum power obtained with oil in the Admiralty experiments in the *Surly* with small-tube boilers is less than half that obtainable with coal. When burning the oil beyond a certain rate dense volumes of smoke are formed; but with that progressive spirit which has been characteristic of the engineering branch of the service during Sir John Durston's *régime*, tests are being continued with the view of determining the best method of utilizing the special advantages of the oil fuel. As an auxiliary to coal, and burned in conjunction with it, the advantages appear to be considerable; but in any case there are special risks attending its use on board warships, as the recent grounding of a German vessel demonstrated. In this case the oil fuel was liberated and caught fire, causing more damage than the actual grounding.

Mechanical Stokers.—Mechanical stokers are now widely adopted in connection with land boilers, but there are probably only two or three cases where a similar system is adopted on board ship, although there seems a wide field for them, especially if the water-tube boiler with its large grate is likely to come into favor for merchant as for naval practice, because frequent and uniform distribution of coal on the grate is necessary to complete combustion. The system fitted in one or two of the American lake steamers for stoking water-tube boilers is of the chain type, and does not differ materially from the general run of mechanical stokers operated on land. On official trials this stoker gave satisfactory results, the consumption per hour being 33.64 pounds of coal per square foot of grate and 1.998 pounds per horsepower hour; while at 20.62 pounds per square foot of grate the rate was 1.56 pounds per horsepower hour. At the Naval Construction Works at Barrow a stoker for marine use is at the present time being tested, but the results are not yet conclusive.

Superheating Steam.—At the moment the aim not only of the naval but of the merchant marine engineer is to secure higher steam pressures, because upon them largely depends increased economy, and at the same time there is probability of a de-

TABLE V.—PARTICULARS OF CARGO STEAMERS FOR NORTH ATLANTIC TRADE, TO ILLUSTRATE FUEL ECONOMY OF LARGE-CAPACITY SHIPS.

Dimensions.	Draught.	Displacement.	Coefficient of Displacement.	Deadweight.	Speed at sea.	Indicated horsepower.	D. ⅔ constant.	Midship area immersed.	Girth immersed.	Coal per 100 tonmiles.*
ft. *ft.* *in.* *ft.* *in.*	*ft.* *in.*	*tons.*		*tons.*	*knots.*			*sq. feet.*	*feet.*	*lbs.*
390 by 45 9 by 29 6	24 6½	8,640	.69	5,000	13	3,475	266	1,092	87.8	8.
415 " 48 9 " 31 0	25 6	10,240	.696	6,000	13	3,725	277	1,209	92.46	7.1
438 " 51 5 " 32 8	26 3½	11,870	.702	7,000	13	3,970	287	1,314	96.46	6.5
458 " 53 9 " 34 0	27 0½	13,500	.71	8,000	13	4,225	295	1,412	100.	6.05
475 " 55 9 " 35 5	27 11	15,100	.715	9,000	13	4,475	300	1,513	103 64	5.7
493 " 58 0 " 36 7	28 7	16,750	.72	10,000	13	4,725	305	1,610	107.	5.42
521 " 61 2 " 38 9	30 0	19,850	.728	12,000	13	5,200	311	1,780	112.8	4.97
535 " 62 9 " 39 9	30 7	21,470	.732	13,000	13	5,430	313	1,862	115.4	4.8
548 " 64 1 " 40 9	31 3	23,070	.736	14,000	13	5,675	314	1,946	118.	4.66
570 " 66 9 " 42 4	32 4½	26,150	.742	16,000	13	6,130	316	2,097	122.5	4.4

All are three-decked vessels (with shelter deck) to class 100 A 1 at Lloyd's.

* The rate of consumption is assumed in all cases at 1.5 pounds per indicated horsepower per hour.

TABLE VI.—SIZE OF SHIPS LAUNCHED IN THE UNITED KINGDOM, 1892-1900, TO ILLUSTRATE INCREASE IN CAPACITY.

(Prepared from Lloyd's Registry Returns.)

Tonnage.	1892.	1893.	1894.	1895.	1896.	1897	1898.	1899.	1900.
2,000 to 2,999	104	75	100	88	89	73	79	57	47
3,000 " 3,999	67	63	90	75	83	74	141	129	119
4,000 " 4,999	23	18	25	30	23	23	28	39	56
5,000 " 5,999	8	5	14	9	35	15	23	27	26
6,000 " 6,999	5	6	4	6	6	5	13	15	17
7,000 " 7,999	...	1	2	1	4	8	13	9	12

Tonnage.	1892.	1893.	1894.	1895.	1806.	1897.	1898.	1899.	1900.
8,000 to 8,999	...	...	...	} 3	2	2	2	} 4	2
9,000 " 9,999	...	...	...						4
10,000 " 10,999	...	...	...	...	...	} 3	} 4	} 9	} 4
11,000 " 11,999	...	...	...	...	1				4
12,000 and above.	...	...	...	1	...				

velopment in the direction of the use of superheated steam. In this way the waste heat may be further utilized in the uptake as with forced draft. Indeed, on a short trial with vessels so fitted, the steam being superheated to the extent of 57½ degrees Fahrenheit, and the pressure being 267 pounds, the rate of fuel consumption worked out at 1 pound per horsepower per hour; but a possible danger to be strictly guarded against is the multiplication of parts, especially if located in positions difficult of access when the vessel is under way. When a premium is not given for fuel economy, or where it is not liberally divided by the ship's captain amongst the engineers, there is a probability that where the gear is in such warm corners the tendency will be to shirk periodical inspection. These remarks must be accepted in their general sense, and not as specially applied to the case in point, for credit is undoubtedly due to the promoters of this marine superheating arrangement.

Theoretical Economy of High Steam Pressures.—It may not be without interest to show diagrammatically the theoretical advantage which must accrue from the use of high steam pressure. In plotting the curves shown on Fig. 2, a terminal pressure of 15 pounds and a back pressure of 3.5 pounds have been assumed; while the expansion is that of perfect gas (hyperbolic). The lower curve shows the percentage of gain above 100 pounds for the mean pressure which is represented by the upper curve. Thus with steam at 100 pounds pressure the theoretical mean pressure would be 42 pounds per square inch; but with a pressure of 300 pounds the mean becomes 57 pounds, so that the gain as compared with 100 pounds steam is shown to be 35.7 per cent. It will be observed that the gain does not increase in the same ratio as the pressure.

Generally it seems doubtful whether a great advantage can accrue from the use of quadruple compounding until the initial pressure is at least 220 pounds; and thus it comes that the practice of adopting four-stage expansion has not developed to the same extent as was anticipated ten years ago. Of the new steamers added to Lloyd's register during the past nine months, only some 3 per cent. are fitted with quadruple-expansion engines,

and it can scarcely be said that this is due to reluctance to multiply working parts, because the practice of adopting four cylinders and four cranks for three-stage expansion has become very general in passenger steamers, even with pressures of 200 pounds.

Some Difficulties of High Steam Pressures—Pipe Joints and Flanges.—Before entering upon the question of cylinder arrangement, attention may be directed to some of the difficulties which have arisen owing to the use of high steam pressure, especially in connection with the joints for steam and feed pipes—difficulties which have been overcome in naval ships, and which should

FIG. 2.

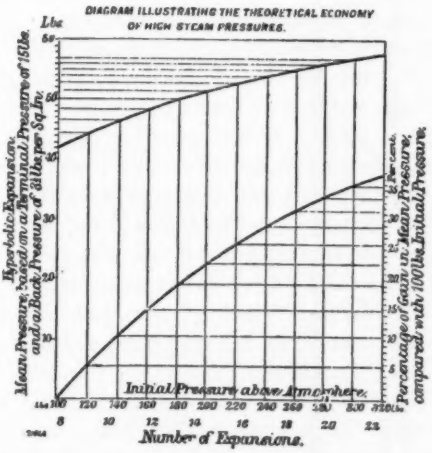


DIAGRAM ILLUSTRATING THE THEORETICAL ECONOMY OF HIGH STEAM PRESSURES.
Lbs.
Hyperbolic Expansion.
Mean Pressure, based on a Terminal Pressure of 15 lbs. and a Back Pressure of 3 lbs. per Sq. In.
Percentage of Gain in Mean Pressure, compared with 100 lbs. Initial Pressure.
Initial Pressure above Atmosphere.
Number of Expansions.

therefore be studied by those engaged in merchant practice. In the first place, the higher steam pressure has necessitated several changes in the material used. Solid-drawn and lap-welded steel tubes are now used in place of copper pipes, and for large valve-boxes and bends gun metal is sometimes used; but cast steel would be used more extensively if castings as thin as considerations of strength would determine could be produced by steel makers. The full use of this material is retarded by the apparent inability to produce sound thin castings.

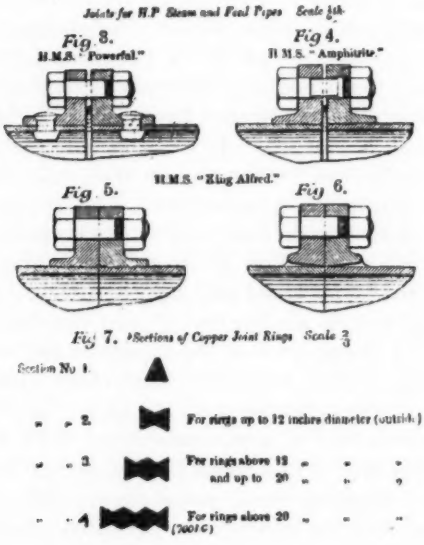
TABLE VII.—SHOWING THE NUMBER OF LARGE SHIPS OWNED BY VARIOUS NATIONS IN 1891 AND 1901.

(Prepared from Lloyd's Registry Returns.)

Vessels.	All Countries.		Great Britain.		Germany.		France.		United States.		Russia.		Spain.		Belgium.		Italy.		Japan.		Holland.		Austria-Hungary.	
	1891	1901	1891	1901	1891	1901	1891	1901	1891	1901	1891	1901	1891	1901	1891	1901	1891	1901	1891	1901	1891	1901	1891	1901
Over tons.																								
13,000	...	10	...	4	...	6	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
12,000	...	8	...	5	...	2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...	...
11,000	...	12	...	7	...	...	...	2	...	3	...	...	...	...	...	...	...	...	...	...	...	...	...	...
10,000	2	21	2	6	...	13	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...	1	...	...
9,000	2	10	2	8	...	...	...	2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
8,000	4	22	3	18	1	3	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...	...
7,000	9	52	2	36	2	10	4	3	...	1	...	2	...	...	1	...	...	...	...	...	...	...	...	...
6,000	15	118	10	71	2	9	3	12	...	6	...	1	...	1	...	1	...	...	...	16	...	...	...	1
5,000	59	252	37	153	12	59	3	3	1	16	...	9	3	4	2	3	1	...	...	1	...	1	...	3

In the earlier warships, with high steam-pressure machinery (260 pounds), all the steam pipes over 3 inches in diameter are of steel; in the later vessels, with 300-pound pressures, the same material is used for all pipes over 1½ inches in diameter. Such steel pipes up to 6 inches in diameter are solid drawn with weldless steel flanges screwed on, while those over this size are lap welded with a butt strap covering the weld, the flange being carefully riveted on. It was found possible to bend the steel pipes up to 4 inches, and it is to be hoped that progress will be made in this direction so as to reduce the number of expansion boxes. The higher pressures also involved change in connection with joints; and many experiments have been made. The diagrams, Figs. 3 to 6, illustrate some types as applied in successive cruisers. Fig. 3 shows the steel flanges fitted to the steel steam pipes of H. M. S. *Powerful*. In this example the surfaces are only machine finished, the actual joint being made by a soft copper ring of triangular cross section. This system gave very satisfactory results under water test, but a few months' actual use brought about such pitting of the steel faces, due to galvanic action, that the joints would no longer keep tight. Another objection to the system was the dropping of the ring owing to its loosening as a consequence of the expansion and contraction of the line of pipe, and its being thus free to take a position eccentric to, and crossing the edges of, the bore. To overcome this the rings shown in Fig. 4 were substituted in H. M. S. *Amphitrite*, in conjunction with a recess formed in each flange, to prevent the ring dropping too far out of place. This effected some improvement, but the trouble from corrosion, unavoidable with copper and steel in contact, led to the system being discarded in favor of the form shown in Figs. 5 and 6. Fig. 5 shows a steel pipe joint with steel flanges, Fig. 6 a copper pipe joint with brazing-metal flanges. Both are finished by hand scraping, and the only material on the joint is a thin wash or paint of red lead and oil. This system has been adopted throughout H. M. S. *King Alfred*, now building at Barrow-in-Furness. The author is of opinion that a simpler, cheaper and efficient form of joint could be used in place of the hand-scraped flanges, viz: a joint

made with asbestos paper (about the thickness of brown paper) soaked in oil, the faces of the flanges being only machined, with no scraping. Indeed, this material was adopted in several instances in the feed-discharge pipes in which the pressure is over 600 pounds per square inch, the joints requiring to be remade at sea. The results of some other tests that have come under the notice of the author are given in the tabular statement subjoined. They include both steel pipes and gun-metal castings, as indicated.


Joints for H.P Steam and Feed Pipes Scale ½
Fig 3.
H.M.S. "Powerful."
Fig 4.
H.M.S. "Amphitrite."
H.M.S. "King Alfred."
Fig 5.
Fig 6.
Fig 7. Sections of Copper Joint Rings Scale ⅔
Section No 1.
" " 2.
For rings up to 12 inches diameter (outside)
" " 3.
For rings above 12 " " "
and up to 20 " " "
" " 4.
For rings above 20 " " "
(Joint)

Arrangement of Engine Cylinders.—It may be said that, so far as high-speed machinery is concerned, the universal practice is to fit a four-crank engine operated from four cylinders, usually on the three-stage compound system, and occasionally for quadruple expansion, the cylinders being arranged on the Yarrow-Schlick-Tweedy system. Ten years ago the greatest power developed in any steamer was 20,000 indicated horsepower, and the highest speed on an over-sea voyage 20.7 knots. Now,

TEST OF EXPERIMENTAL JOINTS.—STEEL PIPES AND STEEL FLANGES.

—	Description.	Remarks.	Results.
A.	Spirally corrugated spigots.	The spiral corrugations are produced by automatic cross-feed in a lathe. Eighteen threads per inch of diameter of face. Both spirals are right-handed, so that they do not fit into each other. Spigot 6⅝ inches inside diameter.	Flanges bolted together and tested by hydraulic pressures: A commenced to leak at 2,300 pounds per square inch; B quite tight at 2,800 pounds (no higher pressure available).
B.	Concentrically corrugated spigot.	Corrugations formed by a chaser, sixteen per inch, those of a pair of flanges dropping into one another. Diameter of spigot = 6⅝ inches.	
C.	Cambered faces.	Machined faces only; finishing cut light, and with very fine feed. About 0.001 inch camber on each flange.	C, D, E all tight at 300 pounds steam, subsequently tested under hydraulic pressure: C commenced to leak at 2,100 pounds; D commenced to leak at 1,850 pounds; E commenced to leak at 2,200 pounds; C, remade with 80-mesh gauze and red lead, was tight at 2,500 pounds.
D.	Roughed.	Flanges surfaced and roughed with a file.	
E.	Flat, machined.	Same as C, but no camber. A, B, C, D all made with thin red lead and oil. E with 80-mesh wire gauze and red lead.	
		GUN-METAL CASTINGS.	
F.	Corrugated.	One flange corrugated concentrically ¼ inch pitch to within ⅜ inch of bore of pipe, the other flanges of pair plain.	All tight under 300 pounds steam pressure. Under water test: F leaked slightly at 1,700 pounds; G leaked slightly at 2,100 pounds. When remade, all commenced to leak at 2,200 pounds.
G.	Grooved.	Slight concentric grooves on flange ⅛ inch pitch, other flange plain with slight camber. F and G made with thin paint of red lead and oil.	

30,000 indicated horsepower is the highest in naval practice, the speed being 23 knots, while in merchant practice nearly 39,000 indicated horsepower has been developed, the mean speed on a transatlantic passage being 23.51 knots, while at the present time there is building a steamer to excel this splendid result. Full credit for this remarkable speed should be given to the company who built the vessel—the Stettiner Maschinenbau Actien-Gesellschaft "Vulcan," of Stettin, who have built for German owners the two fastest merchant vessels afloat, and are now building two to be at least equal in speed.

The low-pressure cylinder was only occasionally divided ten years ago, and the greatest diameter was 113 inches. In the case of the *Campania* such a division was made, and although the power was nearly 50 per cent. greater than in the ship with the 113-inch low-pressure cylinders, the diameter of the largest cylinders was only 98 inches. Experience has shown the enormous importance of balancing forces in the reducing of vibration, so that there has been a further encouragement to divide the third-stage or fourth-stage cylinders: always provided that tandem cylinders are arranged in couples to balance each other. In this way, even although the power has reached in one set of engines 18,000 indicated horsepower, the largest cylinder is only 106.3 inches against the 113 inches in the 10,000 indicated horsepower engine of ten years ago; the relative steam pressures being 220 pounds and 150 pounds. Larger diameters are not desirable, but there is no reason why, with higher steam pressure, a larger number of expansions should not be adopted with multiple cylinders, because any increase in the number of cranks tends to decrease the vibration. Multiple cranks with reciprocating weights can be so arranged as to minimize the disturbing forces, and the result in the case of the *Deutschland*, in which the author recently crossed to America, is that the vertical vibration measured at the extremities of the 684-foot ship was only $\frac{3}{16}$ inch.

Cylinder Ratios.—With increased steam pressure there has come a general increase in the average ratio of low-pressure to high-pressure cylinders. Ten years ago, when the steam pres-

sure was about 158 pounds, the average ratios for twenty-eight triple-expansion engines were as follows:

L.P. / H.P.	I.P. / H.P.	L.P. / I.P.
6.77	2.56	2.64

With an average working pressure of 180 pounds, the mean ratios for forty-five triple-expansion engines built within the past nine months are:

L.P. / H.P.	I.P. / H.P.	L.P. / I.P.
7.55	2.74	2.76

There is some variation in present practice in the ratios of low-pressure over high-pressure, but the great majority of the cases are within one decimal point of the average—7.55, but in the case of the other two cylinder ratios the variations from general practice are more marked. Generally in fast passenger steamers for the Channel service, where the runs are comparatively short, the conditions approximate to those in torpedo-boat destroyers, where reduction of weight is more desired than economy of fuel. And thus in the Channel steamers, with from 160 pounds to 180 pounds boiler pressure, the ratio of low pressure over high pressure is from 5.25 to 5.93. In steamers where coal economy is of importance, as is the case with large passenger liners and cargo boats generally, higher pressures have hardly brought proportionate change in ratio, the view accepted being that a large ratio of expansion is not necessary, or even helpful to propulsive efficiency, when everything is considered from firebars to propeller. With triple-expansion engines for cruisers there has been an increase consequent on higher steam pressure. In the earlier high-pressure cruisers using 210 pounds steam, the ratio of low pressure to high pressure was 5.66, whereas with the 155 pounds steam in former ships with cylindrical boilers the ratio was 5. In later ships, with 250 pounds pressure, it has been increased to 7.1. Turning to quadruple-expansion engines, the ratio of low pressure to high pressure ranges higher than in the case of

merchant steamers with triple-expansion engines using the same steam pressure. In the case of twenty quadruple-expansion engines built recently the ratios are:

L.P.	2d I.P.	1st I.P.
H.P.	H.P.	H.P.
10.25	4.40	1.96

It certainly would be useful to have an authoritative series of tests on this question, and on its bearing upon economy, but it is difficult, if not impossible, in ordinary sea working to approximate the same conditions in several similar ships, eliminating other variants in order to arrive at a definite conclusion on one such element. Data, however, might be collated, say, from some of the fair-sized experimental engines in college laboratories, a notable one being that in the Durham University College of Science at Newcastle-on-Tyne. Such results as have been published regarding its experimental working seem to show that for both triple and quadruple engines the total number of expansions may be kept comparatively low for true useful horsepower efficiency, that consequently the cylinder ratios may be kept small, and that the late cut-offs and consequent drops in receiver pressure so produced can be definitely determined to be of such value as to give the maximum economy, not necessarily on the basis of steam consumption per indicated horsepower, but rather on the steam consumption per effective horsepower per hour. In marine engine research the excellent series of trials carried out by the research committee appointed by the Institution of Mechanical Engineers, 1889 to 1894, is rightly regarded as a standard for reference and guidance for future experiments.

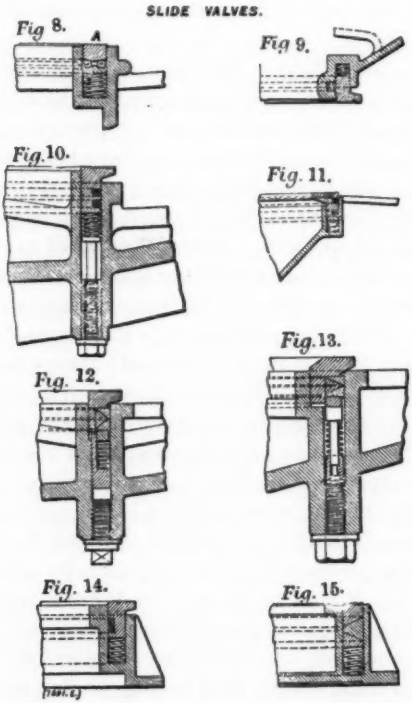
Steam Jackets of Cylinders.—With higher steam pressures, and particularly with superheated steam, the necessity for steam-jacketing in the high-pressure cylinders at least is not so great; but there are few cases in first-class practice where the jackets are not so fitted, although generally in ordinary marine practice liners are fitted in the cylinders to insure a hard close-grained rubbing surface, but very often steam is dispensed with in the jackets. Recent trials with H. M. S. *Argonaut* showed that better

results were got without using steam in the jakets, and the same result was shown in some more recent trials with the machinery of H. M. S. *Hyacinth*, made under the supervision of the Water-Tube Boiler Committee. In the slow-running engines of the merchant service, having an early cut-off, jackets are still found to be beneficial, but only to a limited extent, and there can be no doubt that as pressures increase the use of steam in jackets will be dispensed with.

Slide-Valve Relief Rings.—The changes which experience with higher steam pressures have necessitated in the design of slide-valve relief rings for intermediate and low-pressure cylinders are shown on Figs. 8 to 15, subjoined, the rings being illustrated as mounted in the slide-valve casing doors. Figs. 8 to 10 represent rings as fitted for the intermediate-pressure and low-pressure slide-valves of naval engines with a steam pressure of 155 pounds per square inch, as was usual prior to the adoption of the water-tube boiler. In Fig. 8 the ring A which bears on the back of the slide valve is of bronze, and steam is prevented from passing around the back of it by the two rings of rubber-centered asbestos packing shown behind it, and kept pressed against the walls of the recess by the springs acting through the beveled rings. In Fig. 9 a Ramsbottom ring is substituted for the asbestos rings. Fig. 10 is packed by Ramsbottom rings, but an improvement is effected on the system shown in Fig. 9 by the application of tap bolts forming an adjustable abutment for the springs. This enables the pressure of the ring against the valve and of the valve against the face to be varied. In Fig. 11, which is an arrangement fitted to an engine working with steam at an initial pressure of 220 pounds, this adjustment was not fitted, although the example is more recent than to Fig. 10, but the engines to which they were supplied were of very light type.

Figs. 12 and 13 illustrate the arrangement in use in the engines of naval vessels where the boiler pressure is 300 pounds. The former (Fig. 12) is an early example of the Vickers ring system, which has given very satisfactory results. In this case steam is prevented from passing by metallic packing rings of wedge-shaped sections. The load is adjustable by tap bolts and wash-

ers, as in Fig. 10, but the addition is made of a stop to prevent the valve from lifting off its face more than will allow any accumulated water to be safely forced out of the cylinder. Fig. 13 is a later and improved form developed from Fig. 12. The earlier design, Fig. 12, suffered through having to be made to suit



the casing covers. In the later arrangement the cover was designed to suit the rings, and thus a better form of ring was made possible. The tail of the spring-pad piece is clear of the bottom of the hole in the end of the adjusting tap bolts, so that the valve can lift from its face as in the other examples, the amount of lift being limited to any desired amount by other long tap bolts fitted

at certain points on the same pitch circle as the spring adjusting bolts.

Figs. 14 and 15 are examples from recent mercantile marine engines working with steam of an initial pressure of 200 pounds and 175 pounds per square inch. The latter of these two arrangements embodies the metallic packing devices used in recent naval practice.

Fig. 16.
"Campania" (1893).
30 000 I.H.P.

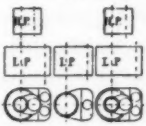


Fig. 17.
"Kaiser Wilhelm der Grosse" (1898). 28,000 I.H.P.

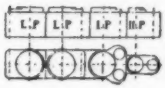


Fig. 18.
"Deutschland" (1900)
35,000 I.H.P.

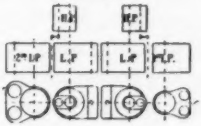


Fig. 19.
H.M.S. "King Alfred" (1901).
30,000 I.H.P.
(*See Plates* 10 *to* 13).

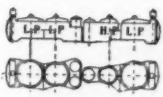


Fig. 20.
"Kronprinz Friedrich" (1901).

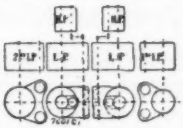
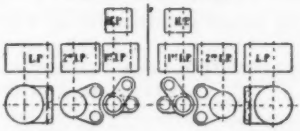


Fig. 21.
"Kaiser Wilhelm II." (1902).



Piston Speed.—Reference has already been made to the increase in piston speeds; in the case of fast ocean-going steamers, as well as in naval ships, there has been a marked increase. The following table gives the speeds for the various types:

	Piston speed per minute.	Stroke.
	ft.	*ft. in.*
Oceangoing passenger steamers of high speed	950	5 6
Intermediate oceangoing steamers	750	4 6
Cargo steamers	530	4 0
High-speed cross-channel steamers	880	2 9

High piston speeds necessitate more attention being given to the lubrication of all working parts, especially of the crank-pin and main bearing brasses. Advantage has been found to accrue from the grooving of the bottoms, as well as the tops, of all

crank-pin, main bearing, and crosshead brasses, as it insures free circulation of the lubricating oil. It can scarcely be said that a large proportion of recent accidents or breakdowns have been due to high speed of rotation, care in selection of the materials of construction and in the design of working parts having reduced to the minimum the chances of failure, while at the same time inspiring those in charge of machinery with increasing confidence.

The Diameter and Strength of Shafting.—There have been frequent failures of tail-end shafts, which have led the various registries to modify their rules in the direction of a greater margin of safety, while special recommendations have been made to prevent corrosion in the stern tube; but it may suffice to give a table showing the increase in size of shafts required by the various registries. The sizes are worked out for a three-crank vertical triple-expansion engine having cylinders 23 inches, 38 inches, and 63 inches in diameter with a stroke of 45 inches, the working steam pressure being 180 pounds per square inch.

COMPARATIVE DIAMETERS OF SHAFTING FOR AN ENGINE OF THE SAME POWER IN 1890 AND 1900 BY VARIOUS AUTHORITIES.

	Crankshaft.		Thrust.		Tunnel.		Propeller.	
	1890.	1900.	1890.	1900.	1890.	1900.	1890.	1900.
	ins. dia.	*ins. dia.*	*ins. dia.*	*ins. dia.*	*ins. dia.*	*ins. dia.*	*ins. dia.*	*ins. dia.*
Lloyd's	11 3/4	12 3/8	11 1/4	12 3/8	11 1/2	11 3/4	11 3/4	13
Board of Trade	11 7/8	11 7/8	11 7/8	11 7/8	11 1/4	11 1/4	11 7/8	12 1/2
British Corporation	11 3/4	12 3/8	11 3/4	12 3/8	11 1/4	11 3/4	12 3/8	12 3/4
Bureau Veritas	12 1/8	12 1/2	12 1/8	12 1/2	11 7/8	12	12 1/8	14 1/8

The percentages of increase in the strength of the above shafts, made to existing rules, as compared with the rules dated 1890, are as follow:

	Crank shaft.	Thrust shaft.	Tunnel shaft.	Propeller shaft.
	per cent.	*per cent.*	*per cent.*	*per cent.*
Lloyd's	17	17	14	36
Board of Trade	0	0	0	16.5
British Corporation	17.5	17.5	14	9

Stresses upon Materials in Cargo Steamers v. *Torpedo-Boat Destroyers' Engines.*—While dealing with the subject of the strength of materials, it may not be without interest to indicate the extremes met with in modern marine-engineering practice, as exemplified by the case of modern cargo steamers' engines and the propelling machinery of a 30-knot torpedo-boat destroyer. In Figs. 22 and 23 there is given a contrast diagram (drawn to the same scale) of engines for each vessel, and the table below shows the stress in pounds per square inch on various parts of the two engines. From this it may be seen that the stress in the case of the destroyer is almost double, so far as the crank shaft and piston rod are concerned. A destroyer is an instrument of warfare, where everything is subservient to the one dominant desideratum—high speed; and the risks run in a naval fight will not be associated only with the machinery.

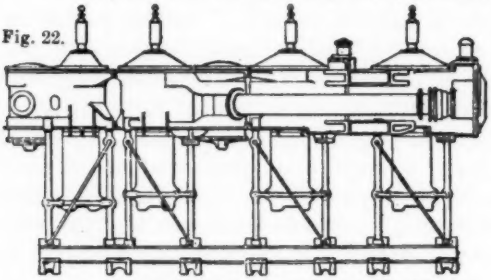
STRESS IN POUNDS PER SQUARE INCH ON VARIOUS PARTS OF MAIN ENGINES FOR CARGO VESSEL AND TORPEDO-BOAT DESTROYER.

	Cargo steamer. 3,750 indicated horsepower. 80 revolutions. 7,500 indicated horsepower combined.	Torpedo-boat destroyer. 3,000 indicated horsepower. 390 revolutions. 6,000 indicated horsepower combined.
	Pounds per sq. in.	*Pounds per sq. in.*
Crank shaft	3,200	6,700
Piston-rod body (tensile)	2,370	5,275
Connecting-rod bolts, bottom end	5,200	8,875
Piston-rod screw	4,150	9,150
High-pressure cylinder barrel at test pressure	4,175	4,400
Intermediate-pressure cylinder barrel at test pressure	3,230	4,700
Low-pressure cylinder barrel at test pressure	2,580	2,230
Factor of safety, connecting-rod bolts	12	7·575
Factor of safety, piston-rod body	26.4	12.75
Factor of safety, piston-rod screw	13.2	7·35
Minimum tensile strength, steel, tons	28	30
Minimum tensile strength, cast iron, tons	8	9

Typical Engines Illustrative of General Practice.—Two steamers successively built for the service of the Lancashire and Yorkshire and London and Northwestern Railway Companies between

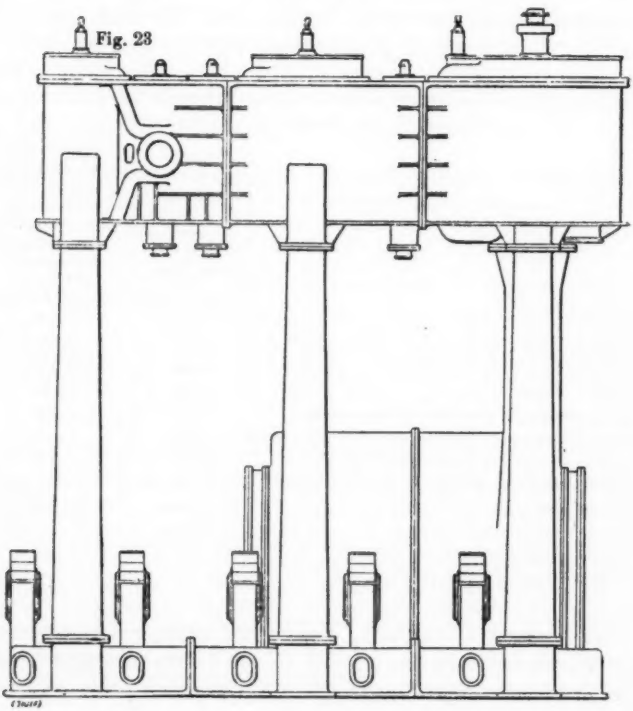
Two Engines of approximately 3,000 H.P. compared.
Torpedo Boat Destroyer Engines, 3,000 I.H.P.

Fig. 22.



Merchant Vessel Engines, 3,000 I.H.P.

Fig. 23



Fleetwood and Belfast, serve to show in what direction changes have been made in channel-steamer practice. The *Duke of Lancaster* was built in 1894, and the *Duke of Cornwall* in 1898. They are practically identical ships. It was stipulated that there should be a large reserve of power, in order that a voyage ordinarily completed in 6½ hours might be accelerated to 5½ hours to "catch the tide." Both have twin screws. The earlier boat was fitted with three-crank triple-expansion engines,

$$\frac{24 \text{ inches} - 36 \text{ inches} - 55 \text{ inches}}{33 \text{ inches}} \times 160 \text{ pounds},$$

developing 5,400 indicated horsepower at 150 revolutions. The later boat has four-crank triple-expansion engines,

$$\frac{22\frac{1}{2} \text{ inches} - 34 \text{ inches} - 38\frac{1}{2} \text{ inches} - 28\frac{1}{2} \text{ inches}}{33 \text{ inches}} \times 180 \text{ lbs.},$$

indicating about 5,700 indicated horsepower at 160 revolutions. The rise in boiler pressure will be noticed, and the increase in revolutions and, consequently, of piston speed. The later engine is arranged on the Yarrow, Schlick and Tweedy balancing system.

A similar comparison between two cargo steamers may be suggested by reference to the *Volta*, completed in 1892, and *Sokoto*, constructed quite recently. Both are for the same owners, and work in the same trade. The *Volta* has single-screw triple-expansion engines,

$$\frac{23 \text{ inches} - 38 \text{ inches} - 61 \text{ inches}}{42 \text{ inches}} \times 160 \text{ pounds},$$

the power being 1,400 indicated horsepower at 70 revolutions, the specified piston speed being 500 feet per minute. The *Sokoto's* engines are

$$\frac{23 \text{ inches} - 38 \text{ inches} - 63 \text{ inches}}{45 \text{ inches}} \times 180 \text{ pounds},$$

single screw, the power being 1,800 indicated horsepower at 85 revolutions, the piston speed thus equaling 650 feet per minute. The only other notable changes are the addition of a feed heater to the later boat, and the substitution of a propeller having cast-

steel boss and bronze blades for the cast-iron propeller used in the earlier ship.

The t. s. s. *Ortona*, built in 1898 for the Pacific Steam Navigation Company, may be considered as an example of present-day shipbuilding and marine engineering, as she is intended to maintain an all round fairly high ocean speed on one of the longest voyages in the world, carrying a good paying cargo (proportionally much greater than that carried by fast Atlantic liners), in addition to a large number of passengers of all classes. Such considerations as these put a limit on the speed at which voyages may be economically made. The cylinders of the *Ortona's* engines are 30 inches, 50 inches and 83 inches in diameter by 54 inches stroke, and on trial the mean indicated horsepower was 8,550 indicated horsepower at 81.9 revolutions.

Enclosed Engines.—The high speed of rotation of the destroyers' engines, which run up to 420 revolutions per minute, may make it almost a necessity to adopt the closed-in system in combination with forced lubrication. The advantage of this will be appreciated when it is stated that the space between the twin sets of engines in most of the destroyers does not exceed 3½ feet, the starting platforms being as a rule at the forward end.

Any doubt entertained as to the practicability of carrying out the system in destroyers of 30 knots speed has been dissipated by the success of one of the British boats, which is working satisfactorily with closed engines and forced lubrication. The new arrangement, however, calls for a greater faith on the part of the engineer in charge, who is not able to see at all times the condition of nuts and pins. But as the whole subject has already been discussed at the Institution of Mechanical Engineers, in a paper read in July, 1897, by Mr. Alfred Morcom, on "High-Speed Self-Lubricating Steam Engines," it is not necessary here to do further than indicate progress.

Auxiliary Machinery: Piston Packings.—The increase in steam pressures has involved several problems in connection with the auxiliary machinery on board ship. In some of the early high-pressure naval machinery there was considerable leakage in the auxiliary as well as main engines through piston and slide-rod

glands having asbestos packing. In one case a packing was substituted consisting of powdered white metal, black lead and mineral grease mixed together, and held in position in the glands or stuffing-box by vulcanite rings inserted at top and bottom. It proved efficient, and even in the case of some of the main-engine glands this same packing was substituted for asbestos, the ordinary metallic packing being retained in the upper gland; but here the retaining rings were of metal instead of vulcanite, and there was no leakage during the two years this packing was in use in the lower gland of the high-pressure cylinder of an engine when working at all powers from 2,000 to 12,000 horse-power. In the case of an engine for running a dynamo the tightness was of corresponding duration. A development in the opposite direction has recently taken place, it having been found that under usual circumstances metallic packing is unnecessary for the piston and slide-rods of the low-pressure cylinder. Soft packing in these positions behaves satisfactorily, and does not require the skill in attention and overhaul that many metallic systems involve. In the Navy most low-pressure glands are now being fitted with soft non-metallic packings.

The question of the coal consumption of auxiliary machinery has occupied much attention, and valuable data are to be found in the admirable papers read by Sir John Durston, K. C. B., Engineer-in-Chief of the Navy, and Mr. H. J. Oram, Chief Inspector of Machinery, at the Institution of Civil Engineers, and by Sir John Durston, at the Institution of Naval Architects. There can be no doubt that a saving could be effected by compounding many of the engines; but in naval ships, at least, the necessary increase in weight is an objection. Flat slide valves, with relief rings at the back where necessary, should replace piston slide valves. Nearly all the piston slide valves in the auxiliary machinery of naval ships, at all events, have, until recently, been solid; and although they may be tight when new, they soon wear, with the result that constant leakage to the condenser goes on. Where such piston valves require to be fitted, they are now applied with "restricted expansion" rings similar to those fitted to the main pistons.

The closed exhaust system of dealing with the exhaust steam from auxiliary machinery, introduced by Sir John Durston, consists in connecting the auxiliary exhaust mains to the evaporator steam coils, and to the low-pressure cylinder chests of the main engines through suitable stop valves. The direct connections to the auxiliary condensers are kept closed by spring-loaded valves set to lift when the pressure in exhaust pipes rises above a desired amount. Sentinel valves are fitted and set to blow off at 30 pounds (above atmosphere). The result of this arrangement is that the condensers only receive such steam as the evaporators cannot condense in their heating coils. The connections to the low-pressure chests when opened allow the exhaust of the auxiliaries to be used in the low-pressure cylinders. The auxiliaries have to work against a higher back pressure, but as they are at most two-stage compound engines, this leaves them perhaps as large a range as is desirable, and steadies their running. The great advantage of the system is that it allows the latent heat of the exhaust steam to be usefully employed, instead of passing to the condenser.

It has been suggested that much of the auxiliary machinery should be operated by electricity, and it seems probable that where extensive use is made of the current, admitting of an economical system of generation, good results might accrue, especially in the driving of fans and other gear situated at present at considerable distance from the main steam leads. But the experience of some of the superintending engineers and also of the United States naval authorities, who have tried the electrical system, "has not been altogether favorable." One difficulty to be guarded against is the application to such mechanism as requires a great initial impulse—as in the case of anchor gear, for instance, where the steam stored up overcomes a sudden and heavy load. There are reasons also for not adopting electric drive for any of the auxiliaries upon which the main engines are directly dependent. In the case of some of the auxiliaries, too, efficiency must be the first consideration apart from economy.

Direct-Acting v. *Crank Pumps.*—In this connection, some results of trials made with crankshafts and direct-acting pumps are

recorded on Table XI. The direct-acting pumps were all of the Weir standard pattern. The foot notes on Table XI, give the dimensions of cylinders and pumps in each case. It will be seen from the table that the steam consumption of the crankshaft pump, both when working high pressure and compound, is much higher than with the direct-acting pump, the steam consumption for the simple working being 67.8 pounds, as against a mean of about 48 pounds, whereas with compounding the difference is equally marked, and the mechanical efficiency is quite 10 per cent. better with the direct-acting pumps.

The Propeller.—The length of this paper precludes any detailed reference to the subject of propellers. There is a growing tendency in favor of twin screws, largely because of the security they afford against complete breakdown, and something like 5½ per cent. of all steamers now constructed are of this type. Triple screws have been adopted for one or two merchant vessels for shallow-river service, three-cylinder engines on the triple-compound system being fitted athwart the ship with cranks running fore and aft, each driving a separate screw, and connected by a coupling rod at the forward end of each crank. This arrangement secured the advantage of triple expansion, and enabled the screws to be of less diameter than would have been the case with single or twin propellers. These instances, however, are exceptional. In naval practice there are several applications of triple-screw propulsion, each screw having an independent engine. This system, however, was adopted not so much because it increased the propulsive efficiency at full power—it is very doubtful if such is the case—but because it enabled the center engine and screw to be alone used for comparatively low speed, with the two side screws running idle so as to reduce the consumption at cruising speed; but it is possible that this may be achieved by other means, especially if the three propellers are found to reduce the propulsive efficiency. It may be incidentally mentioned that, to achieve the same result, an engine was built some years ago in which a fourth or "additional" cylinder was introduced to act as a first-stage cylinder or to be idle, as the conditions suggested. The cylinder had all the necessary con-

necting pipes, passages, links and valves, but when the engine was working at full power, the piston of the added cylinder was retained in equilibrium, the steam passing to the second-stage cylinder, where it worked at its initial or full pressure. When steaming at low power the extra cylinder came into operation, and thus there were four stages of expansion. This system was fitted to a Russian volunteer ship, the *Queen Olga*, but the vessel has been continuously worked at full power, so that there are no data as to the actual economy under the varying speeds of naval maneuvering.

Steamship Speeds.—In the ten years considerable progress has been made in the direction of speed. In 1891, there were only eight vessels whose speed exceeded 20 knots; now there are fifty-eight, as shown in Table X which records the number of fast ships owned by the various nations at the end of last year and in 1891. The vessels between 19 and 19½ knots speed have doubled, numbering now thirty-four; and Great Britain, it is interesting to note, holds a high position, due in part to the number of high-speed channel steamers in the Irish Sea, North Sea and English Channel. The French, Belgian and Dutch high-speed steamers are principally channel boats, but the five German vessels and the four of the United States are ocean liners. The highest speed attained ten years ago was 25 knots, recorded for a British-built Brazilian torpedo boat, the fastest British Navy torpedo boat being 22½ knots; now the record is held by the steam turbine-propelled destroyer *Viper*, of His Majesty's Navy, which has attained a maximum of 37.113 knots, and a mean for one hour of 36.581 knots. The highest ocean speed ten years ago was 20.7 knots by the *Paris* and *New York;* to-day the highest speed on an ocean run has been achieved by the German liner *Deutschland*, which has maintained an average of 23.51 knots, while the best speed got with channel steamers is that attained by the City of Dublin Steam Packet Company's steamers on the cross-channel run—23.62 knots with steam of 171 pounds pressure, the power being 8,500. These vessels, of 3,096 tons, builder's measurement, have engines of the

four-cylinder triple-expansion type, with four double-ended boilers worked on the closed-stokehold system.

A Comparison of High-Speed Steaming: Weights and Space Occupied.—On Table VIII, there is given a list of dimensions of typical ships of to-day, including the two fastest Atlantic merchant vessels, the *Deutschland* and *Kaiser Wilhelm der Grosse;* the fastest armored cruiser, H. M. S. *King Alfred;* the largest ship ever built, the *Celtic;* a typical channel steamer with a cruiser of corresponding size; and, finally, a representative moderate-sized merchantman. There are several points of interest in the comparisons, but attention need only be called to one or two. It will be seen that the *Deutschland* is fitted with Howden's system of draft, the *Kaiser Wilhelm der Grosse* has an open stokehold with natural draft, and the *King Alfred* is fitted with the Belleville boilers. And here also we have a comparison between merchant and naval practice. The naval engineer has not only less space, but less weight given him, the power per ton of machinery being almost double that in the correspondingly fast liners, while the superficial area occupied by the engine and boiler space per unit of power is about 25 per cent. less. The ratio of heating to grate area is 39 in Howden's system, 32 in the open-stokehold system, and 31 in the Belleville-boiler system. The comparison may be completed by a statement that in the case of the *New York* and *Paris*, which were the fastest Atlantic liners ten years ago, the power per ton of machinery was 6.75 indicated horsepower—about the same as in the present-day Atlantic liners; the superficial area of machinery space, 0.54 square foot per indicated horsepower, rather more than in the modern liner, and the ratio with the closed-stokehold system of forced draft 38 square feet of heating surface per square foot of grate. Alike in the moderate-sized cargo steamer *Indrani* and in the *Celtic*, the power per ton of machinery is about 50 per cent. less than in high-speed Atlantic liner practice, while the space occupied per unit of power is about double. The comparison of the channel steamer *Duke of Cornwall*, and His Majesty's second-class cruiser *Juno* or *Doris* is the more interesting, as both vessels have cylindrical boilers, and work with a closed stokehold.

TABLE VIII.—DIMENSIONS AND WEIGHTS OF MACHINERY OF TYPICAL MODERN STEAMERS.

Name of ship.....	*Deutschland.*	*Kaiser Wilhelm der Grosse.*	H. M. S. *King Alfred.*	*Celtic.*	*Duke of Cornwall.*	*Juno* and *Doris.*	*Indrani.*
Builders.....	Vulcan Company, of Stettin.	Vulcan Company of Stettin.	Vickers, Sons and Maxim, Limited, Barrow.	Harland and Wolff, of Belfast.	N. C. and A. Company.	N. C. and A. Company.	N. C. and A. Company.
Owners	Hamburg American.	North German Lloyd.	British Admiralty.	White Star.	L. and N.W. Railway Company.	British Admiralty.	T. B. Royden and Co.
Year when completed.....	1900.	1898.	Now building.	1901.	1898.	1893.	1894.
Length over all.....	684 feet.	648 ft. 7½ in.	529 ft. 6 in.	697 ft. 5 in.	325 ft. 6 in.	370 ft. 3 in.	411 ft. 2 in.
Length between perpendiculars	662 feet 9 inches.	625 ft.	500 ft.	680 ft.	315 ft.	350 ft.	399 ft. 9½ in.
Breadth.....	67 feet.	66 ft.	71 ft. 3 in.	75 ft. 4½ in.	37 ft.	54 ft.	47 ft. 11 in.
Depth molded.....	44 feet.	43 ft.	39 ft. 6 in.	48 ft. 4½ in.	17 ft. 6 in.	34 ft. 1⅜ in.	32 ft. 3 in.
Gross tonnage, tons.....	16,502	14,349	8,700	20,880	1,540	3,773	4,994
Draught.....	29 feet.	28 ft.	25 ft. 10½ in.	33 ft.	15 ft. 3½ in.	20 ft. 6 in.	25 ft.
Displacement, tons.....	23,620	20,880	14,200	33,550	2,830	5,600	10,930
Type of engine.....	6-cylinder, quadruple expansion (Schlick system).	4 - cylinder, triple - expansion (Schlick system).	4 - cylinder, triple - expansion (Yarrow, Schlick and Tweedy).	4 - cylinder, quadruple-expansion.	4 - cylinder, triple - expansion (Yarrow, Schlick and Tweedy).	3 - cylinder, triple - expansion.	3 - cylinder, triple-expansion.
Number of cranks.....	4	4	4	4	4	3	3
Diameter of cylinders in each engine.....	36.6″ 36.6″ / 103.9″, 106.3″, 106.3″, 73.6″	52 in., 89.7 in., 96.4 in., 96.4 in.	81½ in., 43½ in., 71 in., 81½ in.	33 in., 47½ in., 68 in., 98 in.	22½ in., 34 in., 38½ in., 38½ in.	33 in., 49 in., 74 in.	27 in., 44 in., 72 in.

Stroke of pistons.....	72.8 inches.	68.8 in.	48 in.	63 in.	33 in.	39 in.	48 in.
Piston speed, ft. per min...	...	885	960	...	880	910	640
Number and type of boilers.....	12 double-ended and 4 single-ended.	12 double ended and 2 single-ended.	43 Belleville with economizers.	8 double-ended.	4 single-ended cylindrical.	8 single-ended cylindrical.	2 double-ended cylindrical.
Number of furnaces.....	112	104	43	48	16	24	8
Steam pressure, pounds...	220	178	Boilers 300, engines 250.	210	180	155	180
Total heating surface, sq. ft.	85,468	84,285	72,001	41,680	10,772	18,750	6,108
Tota lgrate area, square ft..	2,188	2,618	2,313	1,014	317	599	192
System of draft.....	Howden's.	Open stoke-hold.	Natural.	Assisted draft.	Closed stoke-hold forced.	Closed stoke-hold forced.	Natural.
Total indicated horse power.....	38,900	30,000	30,000	13,000	5,520	9,830	2,120
Highest mean speed, knots.....	23.51	22.79	23	16.0	19.75	20	10.75
Superficial area of engine and boiler spaces per indicated horsepower, square feet.....	.382	.42	.346	.96	.405	.44	.949
Total weight of machinery, including water, tons.....	5,670	4,460	2,500	2,975	612	9.4	455
Indicated horsepower per ton of machinery.....	6.86	6.71	12	4.37	9.02	10.88	4.66

Here the naval ship, although working with a lower steam pressure, has the advantage of a higher piston speed, with lighter engine and boiler scantlings, and therefore gets 10.88 indicated horsepower per ton of machinery, as compared with 9 indicated horsepower in the case of the channel steamer.

It may be interesting here to compare the weights of machinery with those of ten and twenty years ago. In 1881 the average for merchant ships was recorded as 4.66 indicated horsepower per ton, while in 1891 the average for cargo boats was 4.8, and is now about the same. For the fastest liner the weight ten years ago was also about the same as it is now—6.7 indicated horsepower per ton, but generally there is now more boiler power and additional weight in the machinery. In channel steamer work there has been an increase in the power per ton of machinery. In naval practice there has been a marked diminution in weight, the rate in 1881 being 6¼ indicated horsepower per ton of machinery, in 1891 10 indicated horsepower per ton, and now 12 indicated horsepower, all for natural draft.

As a complement to this table there is given on Table IX, a comparison of the space occupied by machinery in the latest built naval ships with cylindrical boilers, and with modern water-tube boilers, and in various types of merchantmen, including the high-speed Atlantic liners *Kaiser Wilhelm der Grosse*, *Deutschland* and *Campania*, the immense cargo carrier *Celtic*, the Channel steamer *Duke of Cornwall*, and the general trader *Indrani*. From this it will be seen that the Atlantic liners with cylindrical boilers require fractionally more stokehold floor space per unit of power than the Belleville-boiler ships, the average being about 0.28 square foot, as compared with 0.25, while the cylindrical-boiler warship required 0.35, as indicated by the figures for the *Majestic* and the *Crescent*. In the case of the *Pelorus*, which is fitted with a small-tube express water-tube boiler, the space occupied is greatest, being 0.384. Turning to engine-room space, there is considerable variation, and it is to be noted that in the two latest classes of cruiser there has been a material reduction (0.11 square feet), although the *Campania*, with her five cylinders and three cranks (Fig. 16), comes out at a very low

rate. But it should be remembered that, whereas, in the merchant ship there is no limit to the height of the engine, in warships the necessity for protection makes tandem cylinders impossible. The space occupied per unit of power in Atlantic liners is certainly satisfactory. Here there must be a great pressure put upon the designer to economize space, because of the great value of the area of the various decks; the average revenue per square foot of deck, excluding only engines and boiler spaces and uptakes, in one of the latest liners on the various decks is as follows:

PASSENGER REVENUE POSSIBLE ON EACH TRIP PER SQUARE FOOT OF DECK IN MODERN ATLANTIC LINER.

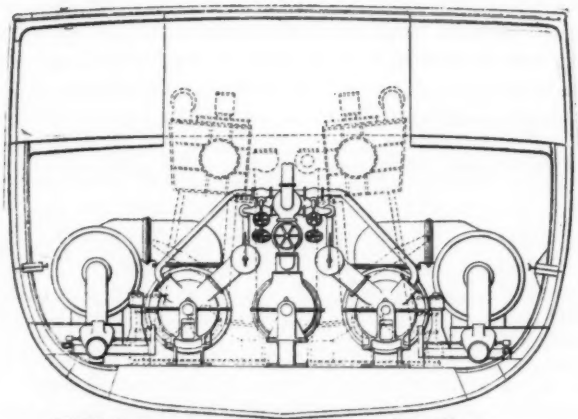
	Summer. Per sq. ft.		Winter. Per sq. ft.	
	s.	*d.*	*s.*	*d.*
Promenade	7	6	4	11
Upper	5	10	4	2
Main	4	2	2	4
Lower	4	3	2	4

When it is noted that this particular ship makes from twelve to fifteen round voyages in the year, it will be recognized that every square foot which the engine designer saves on the four decks indicated insures a possible yearly addition to the passenger earnings of £20, without any appreciable increase to expenses.

The Steam Turbine.—Any review of marine engineering progress would be incomplete without a reference to the possibilities of propulsion by steam turbines; but at the end of a paper already too long, only a casual reference to the subject is possible. In electric-light work the steam turbine has become a most efficient motor, and exhaustive trials have demonstrated its economy in steam consumption, the actual rate of a 1,000-kilowatt set having been 9.19 kilogrammes per kilowatt-hour, which may be accepted as equaling about 12½ pounds per horsepower hour. In the case of a long-distance sea voyage at a uniform speed—and this is the condition prevailing in 99 per cent. of merchant steamers—there can be no doubt of the economy of the turbine. In such case it can be designed for the maximum load, which

would be the average working load. For naval work, where the speed is variable, the same advantages may not accrue, because the steam losses are practically constant irrespective of the power being developed. Where weight is a primary factor, even this

Fig. 24.



COMPARISON BETWEEN THE PARSONS TURBINE (*Fig.* 42) AND RECIPROCATING ENGINES OF 7000 H.P.

Fig. 25.

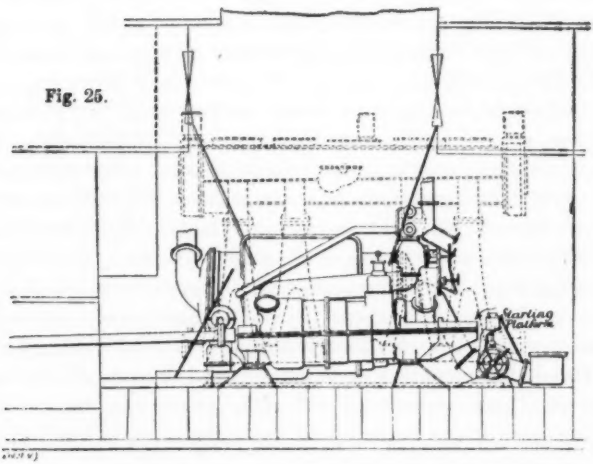


TABLE IX.—SPACE OCCUPIED BY MACHINERY IN TYPICAL MODERN NAVAL AND MERCHANT SHIPS.

TABLE IX.—SPACE OCCUPIED BY MACHINERY IN TYPICAL MODERN NAVAL AND MERCHANT SHIPS.

Type of ship.	Name of ship.	Type of boiler.	Steam pressure. Boilers. Engines.	I.H.P. designed. *a* Full power F.D. *b* Full power N.D. *c* Continuous.	Floor space. Engine room. Length × Mean width.	Engine room. Sq. ft. per I.H.P.	Boiler room. Length × Mean width.	Boiler room. Sq. ft. per I.H.P.	Total square feet per I.H.P.
Battleship, 1895.	*Majestic.*	Cylindrical.	155 / 150	*a* 12,000 / *b* 10,000 / *c* 6,000	ft. ft. 43.5 × 46.0	*b* .200	ft. ft. 79.5 × 45.5	*b* .362	*b* .562
Battleship, 1900.	*Duncan.*	Belleville.	300 / 250	*b* 18,000	52.0 × 46.25	*b* .133	94.0 × 45.5	*b* .238	*b* .371
Cruiser, 1892.	*Crescent.*	Cylindrical.	155 / 150	*a* 12,000 / *b* 10,000 / *c* 6,000	40.0 × 46.0	*b* .184	93.5 × 37.0	*b* .345	*b* .530
Cruiser, 1900.	*Hogue.*	Belleville.	300 / 250	*b* 21,000 / *c* 16,000	60.0 × 47.5	*b* .136	99.0 × 44.0 / 33.0 × 34.0	*b* .26	*b* .396
Cruiser, 1901.	*King Alfred.*	Belleville.	300 / 250	*b* 30,000 / *c* 22,500	67.5 × 47.33	*b* .106	90.0 × 43.75 / 45.0 × 40.75 / 45.0 × 32.0	*b* .24	*b* .346
Cruiser, 1901.	*Monmouth* class.	Belleville & Niclausse.	300 / 250	*b* 22,000	59.0 × 41.0	*b* .11	90.0 × 39.0 / 45.0 × 34.0	*b* .229	*b* .339
Cruiser, 1896.	*Pelorus.*	Normand.	300 / 250	*a* 7,000 / *b* 5,000 / *c* 3,500	37.8 × 34.0	*b* .257	80.0 × 24.0	*b* .384	*b* .640
T.-B. destroyer, 1900.	*Vixen.*	Vickers / Express.	250 / 240	*a* 6,000	29.0 × 18.0	.087	66.5 × 13.75	.152	.239
Channel steamer.	T.-S.S. *Duke of Cornwall.*	Cylindrical.	180	*a* 5,517	27.0 × 33.75	*a* .165	40.0 × 33.0	*a* .24	*a* .405
Cargo steamer.	S.S. *Indrani.*	Ditto.	180	*b* 2,120	28.4 × 32.5	.436	32.0 × 34.0	.513	.949
Atlantic liner.	*Kaiser Wilhelm der Grosse.*	Ditto.	178	*b* 28,000	72.0 × 55.0	.14	73 × 54 / 73 × 54	*b* .28	*b* .42
Atlantic liner.	*Deutschland.*	Ditto.	220	*a* 35,000	87.0 × 56.0	.139	80 × 55 / 80 × 54 / 62 × 21	.286	.425
Intermediate liner.	*Celtic.*	Ditto.	210	*b* 13,000	.....	.....	.....	.....	.96
Atlantic liner.	*Campania.*	Ditto.	165	*b* 30,000	About 50.0 × 56.0	.093	About 82.5 × 55.5 / 67.5 × 55.5	.277	.371

need not militate against its adoption, and thus it would seem as if the future would see a great development in this direction. Figs. 24 and 25 illustrate the design for a Parsons turbine-driven steamer of 7,000 horsepower with three shafts, two of which are driven by low-pressure turbines, while the center-shaft motor is of the high-pressure type. The turbines for driving the ship astern are incorporated with the low-pressure system, being fitted in the exhaust casings with a valve to pass the steam direct from the boiler to the astern turbines, in which case the low-pressure ahead turbines on the same shaft rotate in a vacuum. At the same time, the steam is cut off from the high-pressure turbine, which also runs idle in a vacuum. It will thus be seen that for driving ahead the steam passes through the high-pressure turbine, thence through self closing valves to the two low-pressure turbines, and finally to the condenser; but should the order be given to reverse the engines, the main admission valve is closed, and the steam is then passed through other valves to the two astern turbines, which, being of large area, develop considerable power and speed sternwards. The self-closing valves prevent the steam passing to the high pressure motor. The change is easily made, as all the valves are actuated from the same platform, and the arrangement is such that either of the side propellers may be driven ahead or astern separately. As to the relative space occupied, the sections show the difference at a glance, and the weight and space occupied for turbine machinery and reciprocating engines of 7,000 indicated horsepower are as follows:

	Reciprocating engines.	Turbine machinery.
Weight in engine rooms and tunnel complete, tons.....	270	190
Floor space in engine room, square feet.....	911	911
Cubic capacity required by engines, cubic feet.....	14,430	10,500

The success of the Parsons' turbine has brought several others into the field, and although experiments have been made at Barrow-in-Furness with several of these, they are not sufficiently advanced or conclusive to enable results to be given here. The seasons' work of the turbine-driven steamer *King Edward*, built on the Clyde, will also yield most important data.

TABLE X.—SHOWING THE NUMBER OF FAST SHIPS OWNED BY THE PRINCIPAL MARITIME NATIONS IN 1880 AND 1901.

(Prepared from Lloyd's Registry Returns.)

Vessels.	All countries.		Great Britain.		Germany.		France.		United States.		Belgium.		Russia.		Holland Austria-Hungary, Italy, Japan, Roumania, Chili, Spain, Sweden and Denmark.	
	1891.	1901.	1891.	1901.	1891.	1901.	1891.	1901.	1891.	1901.	1891.	1901.	1891.	1901.	1891.	1901.
knots.																
20 and over	8	58	8	32	...	5	...	7	...	4	...	6	...	1	...	3
19 and 19½	17	34	8	21	6	2	...	3	...	...	3	3	...	4	...	1
18½	6	8	5	5	1	3	...	...	...	...	...	...	...	...	...	...
18	13	39	12	33	...	2	...	...	...	...	...	...	...	...	1	4
17½	24	26	11	13	3	1	10	12	...	...	...	...	...	...	...	...
17	18	64	13	42	4	1	1	5	...	5	...	3	...	...	...	8
16½	24	23	...	15	...	1	...	5	...	1	...	...	...	...	...	1
16	9	70	17	41	2	7	1	3	1	10	...	...	...	...	3	9
15½	43	34	5	13	...	8	1	1	...	9	...	...	...	...	3	3
15	41	121	38	78	...	4	3	8	...	16	1	1	...	2	1	12

TABLE XI.—STEAM-CONSUMPTION TRIALS OF CRANK-SHAFT AND DIRECT-ACTING PUMPS, WORKING NON-CONDENSING.

Type of pump	Crank shaft pumps.			Direct-acting pumps.			Direct-acting pumps.	
Simple or compound	Simple.	Compound.	Compound.	Simple.	Simple.	Twin compound.	Simple.	
Trial number	A	B	C	D	E	F	G	H
Duration of trial, minutes	30	30	30	120	30	30	30	30
Steam pressure at pump, pounds per square inch	127	157	99	108	147	140	106	98
Revolutions, total	383	619	282	1,499	733	308	358	189
Revolutions, per minute	12.76	20.63	9.4	12.45	24.43	10.26	11.93	6.3
Displacement of bucket, total pounds	21,050	34,045	15,510	43,471	153,343	72,500	42,200	22,300
Displacement of bucket, per revolution	55	55	55	29	209.2	235	118	118
Water pressure on gage, pounds per square inch	180	50	35	156	75	180	190	180 to 195
Mean water pressure on bucket, pounds per sq. inch	179.75	51.88	34.62	160.45	73.3	187.8	182.2	186.2
Steam used, condensed and weighed, pounds	364	123	54	498	532	535	488	284
Steam used, per revolution	.95	.1988	.1915	.3307	.7265	1.738	1.363	1.502
Water per pound of steam, pounds	57.9	277	287.5	87.7	288	135.75	86.5	76.4
Foot-pounds work on steam cylinder per pound of steam	29,200	41,490	27,250	37,250	51,830	63,710	40,000	36,610
Foot-pounds work on pump per pound of steam	24,040	33,200	23,000	32,500	48,720	58,970	36,300	33,650
Steam per indicated horsepower, pounds	67.8	47.8	72.7	53.2	38.2	31.1	49.5	54.1
Steam per working horsepower, pounds	82.5	59.7	86.2	61	40.6	33.6	54.6	58.9
Mechanical efficiency	.824	.802	.844	.873	.941	.926	.908	.919

Trial A was made with a simple crank-shaft feed-pump (Weir make), having two steam cylinders 8½ inches in diameter, two pumps 6¼ inches in diameter by 12 inches stroke.

Trials B and C were made with a compound crank-shaft feed-pump (Weir make), having two steam cylinders 5 inches and 8½ inches in diameter, two pumps 6¼ inches in diameter by 12 inches stroke.

Trial D was made with a Weir direct-acting pump (feeding a boiler), having steam cylinder 8 inches in diameter, pump 6 inches in diameter by 15 inches stroke.

Trial E was made with a Weir ballast pump, having steam cylinder 10 inches in diameter, pump 12½ inches in diameter by 24 inches stroke.

Trial F was made with a twin compound Weir pump, having steam cylinders 14 inches and 26 inches in diameter, pumps 9½ inches in diameter by 24 inches stroke.

Trials G and H were made with the high-pressure half of the twin pump, having steam cylinder 14 inches in diameter, pump 9½ inches by 24 inches stroke.

SUMMARY OF RESULTS.

In conclusion, the author desires to gratefully acknowledge the services of many friends who have contributed data for this paper, and to briefly summarize the results attained during the ten years. Steam pressures have been increased in the merchant marine from 158 pounds to 197 pounds per square inch, the maximum attained being 267 pounds per square inch, and 300 pounds in the naval service. The piston speed of mercantile machinery has gone up from 529 feet to 654 feet per minute, the maximum in merchant practice being about 900 feet, and in naval practice 960 feet for large engines, and 1,300 feet in torpedo-boat destroyers. Boilers also yield a greater power for a given surface, and thus the average power per ton of machinery has gone up from an average of 6 to about 7 indicated horsepower per ton of machinery. The net results in respect of speed are that while ten years ago the highest sustained ocean speed was 20.7 knots, it is now 23.51 knots; the highest speed for large warships was 22 knots, and is now 23 knots on a trial of double the duration of those of ten years ago; the maximum speed attained by any craft was 25 knots, as compared with 36.581 knots now; while the number of ships of over 20 knots was eight in 1891, and is fifty-eight now. But probably the result of most importance, because affecting every type of ship from the tramp to the greyhound, is the reduction in the coal consumption. Ten years ago the rate for ocean voyages was 1.75 pounds per horsepower per hour; to-day, in the most modern ships, it is about 1.5 pounds. Ten years ago 1 ton of cargo was carried 100 miles for 10 pounds of fuel; whereas now, with the great increase in the size of ships and other mechanical improvements, the same work is done for about 4 pounds of coal—a result which means a very great saving when applied to the immense fleet of over-sea carriers throughout the world.

DESCRIPTION OF THE STEAM ENGINEERING PLANT AT THE NAVY YARD, N. Y.

By Lieutenant C. H. Matthews, U. S. Navy.

Before entering into a description of the new plant it seems appropriate to briefly allude to the disastrous fire which occurred in February of 1899, and which almost completely destroyed the old plant of the Department of Steam Engineering and made it necessary to construct the present one.

After the destruction of the buildings, the construction of machinery and repairs to vessels was carried on under great disadvantages, but in an incredibly short time, through the resourceful energy of Rear Admiral Geo. W. Melville, U. S. Navy, a temporary frame structure was built and equipped with machinery for carrying on the work of repairs on vessels and replacing the machinery of vessels undergoing repairs that was in the shops at the time of the fire and completely destroyed. The quantity of work and the manner in which it was accomplished under the extremely trying conditions, certainly reflects great credit upon those who directed it.

As this temporary shop did not contain any heavy machine tools, it soon became evident, as larger work accumulated, that some means must be devised for handling it. To meet this demand, Commander J. A. B. Smith, U. S. Navy, the head of the department at this yard, soon had one end of the foundry partitioned off, a line of shafting on either side, and an engine installed, all ready for operation by the time the first large tool was delivered. The completion of this shop then enabled the department to handle the heaviest work. The temporary shops were continued until the 1st day of May of the present year, when the new buildings were ready for occupancy. The work of transferring and installing the machinery in the new shops was carried on without any cessation of the current work.

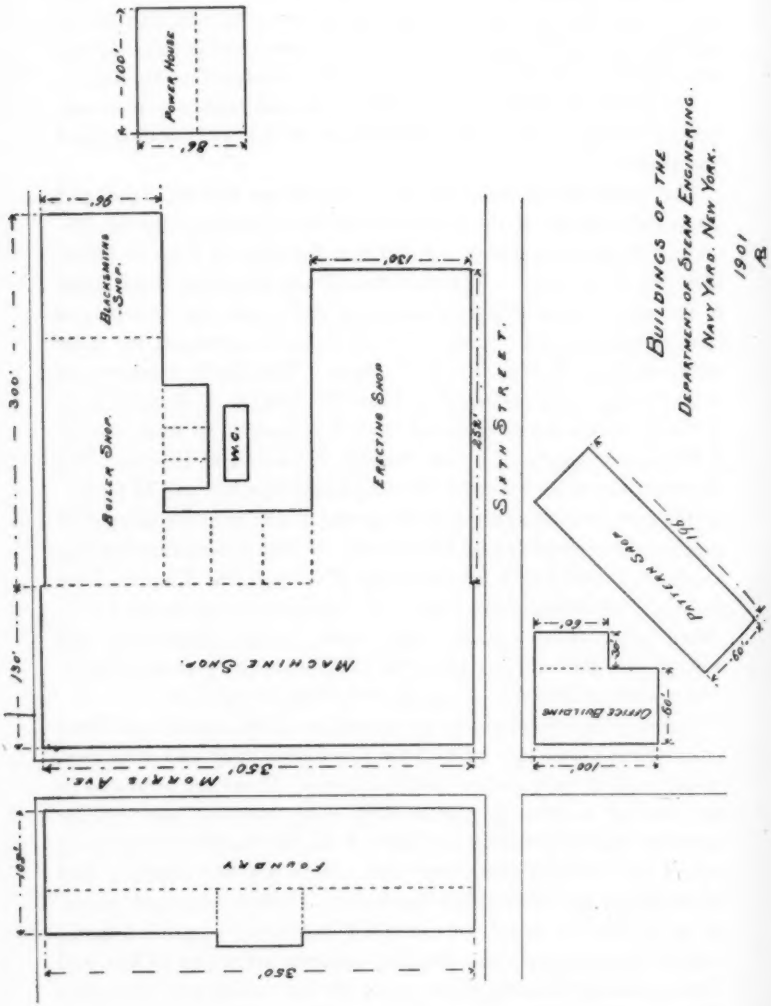
REAR VIEW OF MACHINE SHOP, SHOWING ERECTING AND BLACKSMITHS' SHOP WINGS.

The new plant has been constructed upon a much larger scale than the old one, modern in all respects, and capable of building and repairing any class of machinery and boilers for the Naval service, in the most economic and expeditious manner.

The power is furnished the plant from the central power station by means of electrical distribution, which will be described elsewhere.

The arrangement and type of the buildings and the steam and electrical features of the power house were designed by the Bureau of Steam Engineering, under the direction of Rear Admiral Melville, U. S. Navy. The mechanical and electrical installation of the shops were designed and arranged under the direction of Commander J. A. B. Smith, U. S. Navy, and approved by Rear Admiral Geo. W. Melville, U. S. Navy. The detailed designs for the buildings were prepared by Civil Engineer E. P. Goodrich, U. S. Navy, under the direction of Civil Engineer P. C. Asserson, U. S. Navy, and approved by the Bureau of Yards and Docks. The contract was made with the Westinghouse Electric and M'f'g Co., for the complete equipment of the power house, in accordance with specifications prepared by the Bureau of Steam Engineering, the mechanical part being furnished by Westinghouse, Church, Kerr and Co. Westinghouse type "C" induction motors, for a two-phase alternating current, 220 volts, 3,000 alternation per minute, are used throughout the plant excepting on the travelling cranes, where the direct-current motors are used.

The new buildings comprise a machine shop, 130 by 350 feet; an erecting shop, 130 by 252 feet; a boiler shop and smithery, 96 by 300 feet, only part of which is new. These are arranged in the form of a letter U, the erecting shop forming one leg, the smithery and boiler shop the other, with the machine shop lying across the ends of the other two. Between the erecting and boiler shops are located the machinists' clothes and wash-room, 30 by 56 feet, in which are provided individual expanded metal lockers for clothing; tool-making department, 43 by 56 feet, and a store and tool-issuing room, 35 by 56 feet. These all open into the main shop. In this space is also located the latrine and an extension to the boiler shop, 36 feet 7 inches by 83 feet 9 inches,


BUILDINGS OF THE
DEPARTMENT OF STEAM ENGINEERING.
NAVY YARD. NEW YORK.
1901
A
POWER HOUSE
100'
98'
96'
BLACKSMITHS SHOP.
BOILER SHOP.
300'
130'
W.C.
130'
ERECTING SHOP
238'
SIXTH STREET.
MACHINE SHOP.
350'
MORRIS AVE.
PATTERN SHOP
198'
60'
30'
OFFICE BUILDING
100'
FOUNDRY
350'

which contains the boilermakers' wash room, annealing furnace, hydraulic and pneumatic machinery. The remaining new buildings are the electric-power station, 86 by 100 feet; pattern shop, a two-story building, 60 by 195 feet, and an administration building, two-story, 100 by 60 feet, with a one-story wing, 30 by 60 feet. In addition to these is the old foundry and copper-shop building, 100 by 350 feet, which completes the main plant.

The new buildings are constructed throughout of fire-proof material, the machine and erecting shops being similar in design. The floor space is divided longitudinally in three aisles by the roof columns, the central aisle 70 feet and the two outer ones 30 feet wide. The latter are covered by a single pitch roof of 3½ inches of concrete covered with slate, with a skylight, 13 feet wide, extending the full length of the building, while the central aisle has a double pitched roof of the same material, which has two skylights, 17 feet wide, also extending the full length of the building; it also has a clerestory, 18 feet high; this with the ends and gables is of corrugated iron and glass, the greater part being glass, placed in steel frames on the paradigm system, furnished by Arthur E. Rendle, of New York. The shop is rendered unusually well lighted by the large amount of glass employed. The floors are of cement throughout, and the side walls, to a height of 4 feet, are of brick, the remaining portion being glass. Rear Admiral Melville's idea of excluding all wood work in the construction of these buildings has so far been carried out that even the store-room shelving and bolt bins have been constructed of iron, cast in sections.

In the main aisle of the machine shop are three electric traveling cranes, one Morgan crane of 25 tons capacity being placed on rails over the other two, each of which are of 10 tons capacity. The same arrangement is adopted in the erecting shop, except that the larger one is a Niles, of 40 tons capacity. The machine tools of this shop are about 230 in number, the smaller ones being grouped in the side aisles and driven from line shafts. A portion of the erecting shop is occupied in the same manner. These shafts are driven by 30-horsepower motors, belt connected, one on each end of the shaft, so that either motor can run the

whole line of shafting, by means of a coupling, or only sections of the shaft need be run if so desired. The larger tools, which are driven by direct-connected motors, are placed in the center aisle, under the traveling cranes; a clear space 20 feet wide is left in the center of this aisle the full length of the shop.

There are seventy lathes, varying from 12 inches to 100 inches swing. One with a 100-foot bed, made by the Putnam Machine Tool Co., has 70 inches swing, two head stocks and two tail stocks, which makes it operate as two independent lathes; each head stock being operated by an independent motor of 7½ horsepower each. With one tail stock removed, it is capable of turning a piece of work 70 feet in length. The 100-inch crank-shaft lathe, which was made by Bement Miles & Co., has a 50-foot bed and is 32 feet between centers. It has two independent carriages, one on the front and one on the back, made right-and-left for near approach of the tool posts, and to pass each other on the bed; the lead screw is 4 inches diameter, with a range of screw cutting of twelve threads to one inch to one in twenty-four. The cone is belt driven by an independent 20-horsepower motor, and the mechanism for moving the carriages is driven by a 15-horsepower motor.

There are eleven planers, varying from 20 inches by 20 inches by 5 feet to 100 inches by 120 inches by 22 feet, the later being an open side planer made by Detrick and Harvey Machine Co.

There are twenty vertical and horizontal boring mills. The largest, made by Beaman & Smith, Providence, R. I., is a horizontal-spindle drilling, boring and milling machine, the spindle being 8 inches diameter. The platen or work table is 16 feet long by 14 feet wide; the main column is 15 feet high, mounted on a bed 21 feet 5 inches long by 5 feet wide. It is driven by a direct-connected motor of 10 horsepower.

There are twelve shapers, varying from 15 inches to 48 inches; the latter is a Morton portable with milling attachment, and is driven by an independent motor.

Slotters and key seaters are six in number, the smallest made by New Haven Manufacturing Company and the largest a 48-

INTERIOR VIEW OF MACHINE SHOP, LOOKING NORTH.

inch Morton portable key seater, which is driven by an independent motor.

The milling machines are twelve in number, both plain and universal, among them being a Newton nut-facing machine for nuts from $\frac{3}{8}$ inch to 3 inches.

Radial drills, of which there are nine, contain five 72 inches, by the American Tool Works Company, two being driven by an independent motor, and one 9-foot Bement and Miles universal, also driven by an independent motor. In addition to these are thirty-seven drill presses and sensitive drills, varying from 13 inches to 37 inches, distributed in the shop in a suitable manner.

Gear cutters are three in number. The smallest is a Brown & Sharp 18-inch spur-gear cutter, the largest a Gould & Eberhardt 90-inch, the other is a Gleason 36-inch bevel-gear shaper.

The pipe, bolt, and screw-cutting, machinery are grouped together in one section of the shop, the floor of which is covered with galvanized iron, forming, as it were, a large pan, the purpose of which is to confine the oil dripping from these machines, and prevent its spreading over the floor of the shop. This department has a complete equipment of tools, consisting of eight pipe machines for pipe from $\frac{1}{4}$ inch to 8 inch, and twenty-four miscellaneous screw and bolt-cutting machines, screw slotters and bolt pointers, forming the best assortment of machinery for this work that could be obtained.

The grinding machinery is arranged separately from the other tools, and special men are employed in keeping all cutting tools, etc., in condition; none of this work is done outside this section. There are fifteen of these tools, comprising plain and universal tool and twist drill and fly-wheel grinders, surface grinders and two shaft grinders; the largest, capable of taking 12 feet between centers, was made by the Landis Company. There is also a 125-ton hydraulic bar-straightening press, made by Watson & Stillman.

The heating of this building is done by the steam hot-blast blow-through apparatus, which is being installed by the B. F. Sturtevant Company. It consists of four sets located on platforms overhead; each set consists of three 54-inch fans on one shaft,

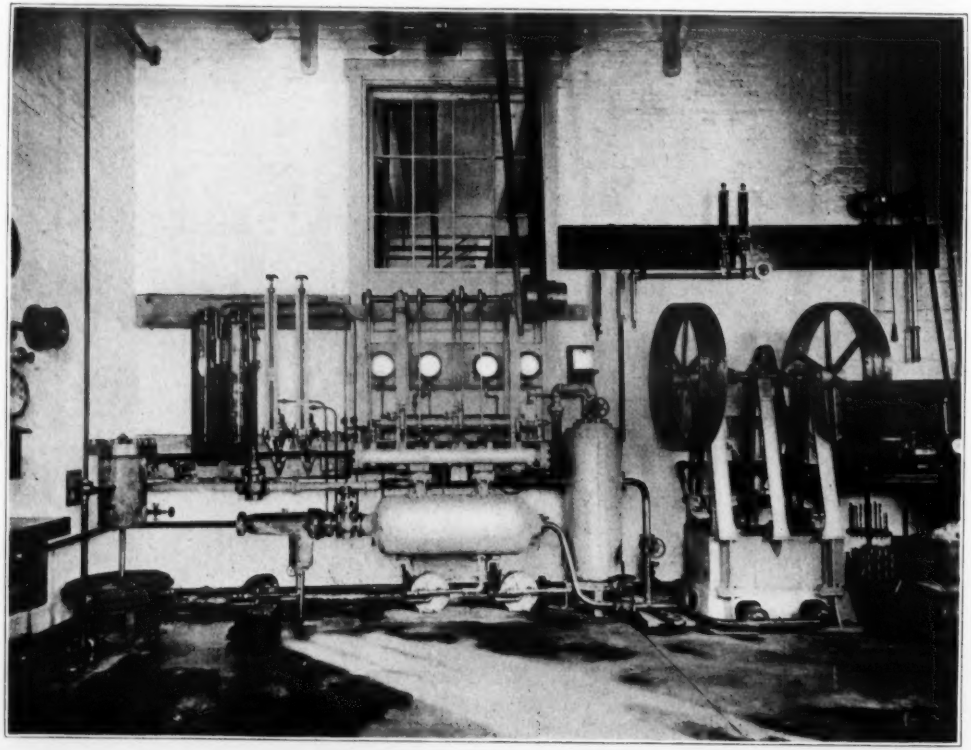
driven by a Westinghouse type "C" alternating-current motor, of 30-horsepower capacity, direct-connected, and a corrugated sectional base heater, containing 6,900 lineal feet of 1-inch pipe, 2,300 square feet heating surface.

The smithery is equipped with fourteen down-draft forges, of various sizes, and a large reverberatory furnace. The blast is supplied by a No. 10 monogram blower, driven by a 7½-horsepower motor, direct-connected, the exhauster being four fans of 30 inches diameter on one shaft, driven by a 10-horsepower motor, direct-connected. This system, with the forges, was installed by the B. F. Sturtevant Company.

The machinery of this shop comprises various drop forge and steam hammers, the largest being a 2¼ ton, made by Wm. Sellers & Co.; one large bull-dozer press No. 6, capable of working as a universal forging machine, driven by 15-horsepower motors, made by Williams & White, Moline, Ill.; one Acme bolt-forging machine, capable of forging and heading bolts from ⅝ inch to 2 inches in diameter. There are three wall cranes of 2,000 pounds capacity and two jib cranes, one 3 tons and the other 8 tons capacity, both driven by electric motors.

The boiler shop contains a complete assortment of light and heavy shears and punches; hydraulic flanging machine, No. 69, Tweddels' system, with two 10-inch vertical plungers and a 6-inch horizontal one, made by Morgan Engineering Company Works; Wood's hydraulic riveting machine with 10 feet gap; 8-foot universal radial drill; Dallet multiple shell-drilling machine; 24-foot plate planer; horizontal and vertical plate-bending rolls—the latter will roll 1¼-inch plates 8 feet wide to a radius of 4 feet; there are also Thorpe-Platt tube bending and testing machines. The power tools number about twenty in all. There are two overhead traveling cranes, one a 5-ton Shaw, electrically driven, and above it a 45-ton Morgan crane, operated by a square shaft running the full length of the shop. It is proposed to equip the latter with electric power also.

The pattern shop is constructed of brick with cement floors throughout, the material in the roof construction being similar to that of the machine shop, with ample skylights. The shop



INDICATOR TESTING APPARATUS.

is located on the second floor, and its equipment of modern wood-working machinery, for pattern making, is second to none and is considered to be a model establishment.

There are in all about thirty tools, power driven, as follows: One Daniels' planer, which will plane 20 feet long, 24 inches wide, and 20 inches high; surface planer, double and single, 30 inches and 26 inches, and a jointer, 30 inches; three circular saws, 14 inches to 24 inches, and a 22-inch swing saw; three band saws, 36 inches, 42 inches, and 48 inches—the latter is a resaw machine; core-box machine; variety machine and wood worker, molding machine, mortising, tennoning, dovetail and doweling machines, and five wood-turning lathes, swing from 15 inches to 84 inches; the latter is a Fay and Scott face-plate lathe. Beside there are about a dozen Olivers' wood trimmers, operated by hand, and two No. 2 universal trimmers. The tools are at present belt driven by an engine through a line of shafting in the center of the shop, but it is the intention to ultimately apply individual motors. The sawdust and shavings are removed by a dust collecting system; the prominent features are a 70-inch mill exhauster fan, driven by a 30-horsepower motor, which draws all refuse from the shop and discharges it into a special dust collector located outside of the building. Each machine is fitted with hoods and piped to the exhauster inlet, sweep-up pipes being provided for removal of refuse from the floor.

The lower floor is used for the storage of patterns, the racks being constructed entirely of metal. The frame work is made of iron tubing and pipe fittings, to which is secured shelves or tiers of heavy wire mesh of galvanized iron. In one corner of this floor is located a test room, 19 by 48 feet, where the most thorough and elaborate devices are provided for the testing of oils, metals, gages and indicators and for the repair and adjustment of the two latter. The main features are a Riehle 150,000-pound tensile, compression, and transverse, metal testing machine, a 30,000 pound oil and friction testing machine of the same make, and a steam indicator testing device, which is constructed on the same lines as the dynamic steam engine indicator tester described by Prof. C. H. Peabody at the second general meeting of the So-

ciety of Naval Architects and Marine Engineers. The design and construction of this machine was made under the direction of Commander J. A. B. Smith and approved by the Bureau of Steam Engineering. Any description of this apparatus or its operation would be too elaborate to admit of discussion at this time.

The foundry is not new, but it is being completely remodeled and modernized. Three new cupolas are being installed, of 5, 7, and 10 tons capacity. The blast is to be supplied by two rotary positive-pressure blowers operated by individual motors.

The Administration Building is constructed of brick with cement floors throughout covered with linoleum, the trim being fire-proof wood. The ground floor is occupied by the offices of the head of the department and his staff of assistants and clerks and the second floor by the draughting offices.

THE CONSTRUCTIVE DEVELOPMENT OF THE DÜRR BOILER IN THE GERMAN NAVY.*

By Von Buchholtz, Naval Constructor, Imperial German Navy.

The Dürr boiler belongs to the few types of water-tube boilers the trials of which sufficiently satisfied the German naval authorities to induce them to fit a considerable number of ships with this class of water-tube boiler.

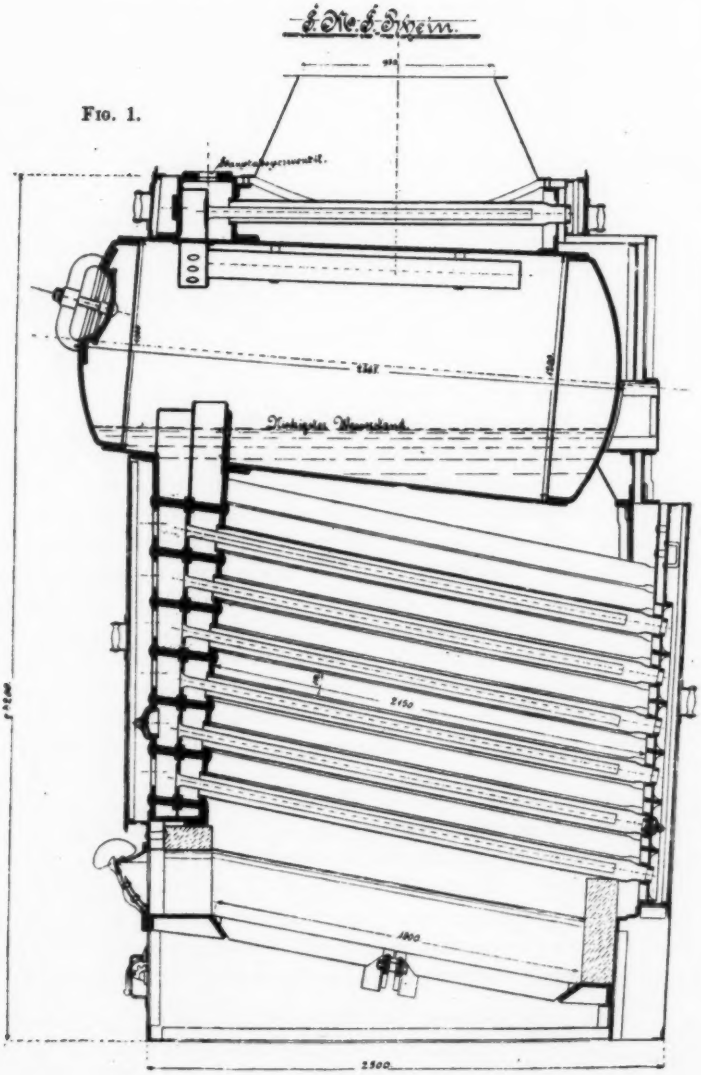
On the whole, the type fulfilled the requirements from the first. Improvements proved, however, desirable in certain features; in the method of cleaning, the circulation of the furnace gases, and in some constructive details. The owners of the patent, the Düsseldorf-Ratingen Röhren Kessel Fabrik, of Ratingen, in Rhenish Prussia, have spared no efforts to perfect their boilers, and have readily acted upon any suggestion made by the German Naval Department, and it may be said that every new boiler constitutes an essential advance upon its predecessor. It will therefore be of interest to trace the development of these boilers, both in their general design and constructive detail, and in their care and attendance. No comparison whatever is aimed at between the Dürr boiler and other approved types of boilers.

THE BOILER OF THE *RHEIN*.

The first Dürr boiler, illustrated in Fig. 1, was built in the year 1893–4 by the Düsseldorf-Ratingen Boiler Works, late Dürr and Co., of Ratingen, for the *Rhein*, which is a small steamer of 350 indicated horsepower, serving as a torpedo training ship. The boiler follows the pattern of the Dürr boilers for river boats, in which the upper cylinder (receiver) is placed in the fore-and-aft

* Translated and reproduced in "Engineering", by permission of the author, from the journal "Schiffbau," Vol. ii, 1901, February 8 and 23, March 8, published by Herr C. E. M. Pfeffer, Berlin.

FIG. 1.



line; it is distinguished by large tubes and wide spacing, and is hence of heavy weight. The water circulation is the same as in all the later styles. The feed water is introduced into the receiver, passes into the front half of the water chamber, thence into the internal tubes, which, fixed in the diaphragm of the water chamber, are concentric to the water tubes proper and reach almost to the lower ends of the latter. Entering the latter tubes, the water is turned into steam and rises through the rear half of the water chamber into the receiver. The jointing of the tubes in the water chamber is effected by forcing the tubes with their conical collars into the conical holes milled in the rear wall.

FIG. 2.

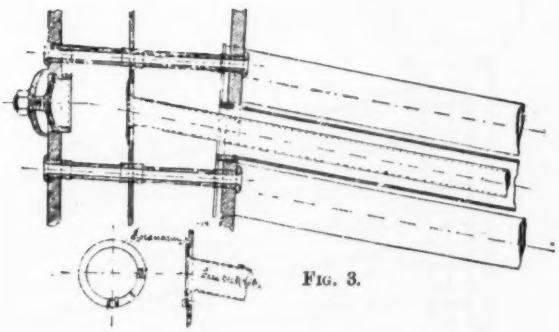


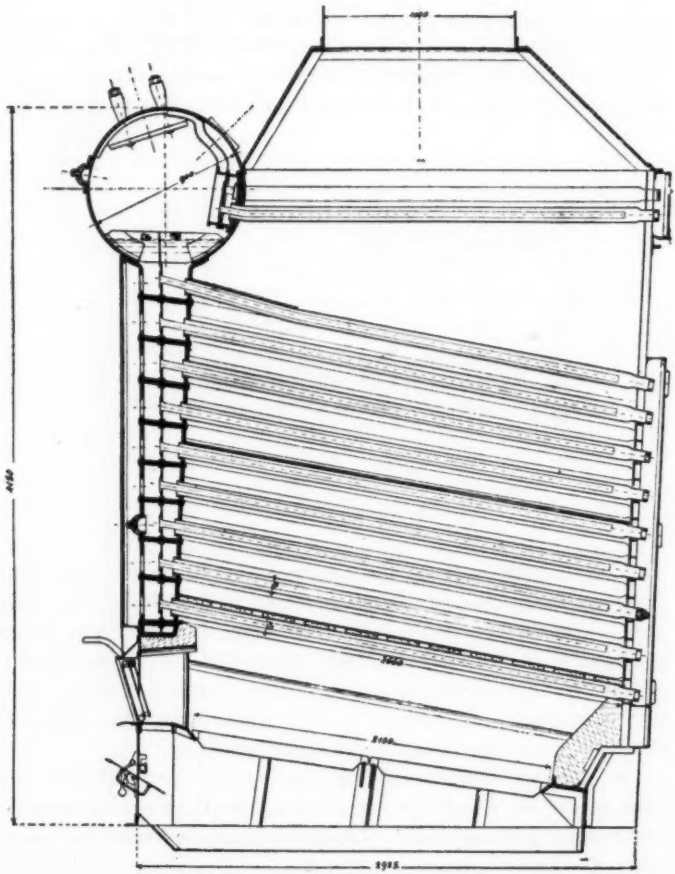
FIG. 3.

The ends of the tubes are inclined to the tube axis, and the tubes themselves are inclined under an angle of 8 degrees, the walls of the header being perpendicular. The fixing of the tubes proper and of the internal tubes is illustrated in Figs. 2 and 3, which also shows the covers applied to the holes in the front wall of the water chamber, opposite to the tubes; the details of the fixing correspond to later practice, however.

On both sides of the system the extreme rows of tubes are bent to the right and left, so as to come close to one another and to form a kind of wall. The superheater, which would more correctly be designated as a steam drier, lies above the receiver

parallel to it, but is separate from it. The steam circulation is as in the boiler tubes. From the front chamber of the superheater the steam passes down the internal tubes and back through the annular space between the internal and external tubes into the rear half of the superheater up to the main steam valve. The

FIG. 4.



collars are welded on the tubes, which are themselves welded by a special patented process; the rear wall supporting the tubes consists of cast iron.

This boiler has been in operation almost without interruption since 1894, and has always given satisfaction, rarely necessitating repairs; the boiler has not been put to any severe tests, however.

THE EXPERIMENTAL BOILER.

Before the Navy resolved to fit the warships of the *Sachsen* class, which were to be rebuilt, with Dürr boilers, a series of continued trials were conducted with a special experimental boiler (supplied by Messrs. Dürr and Co.), both in the Düsseldorf works

FIG. 5.

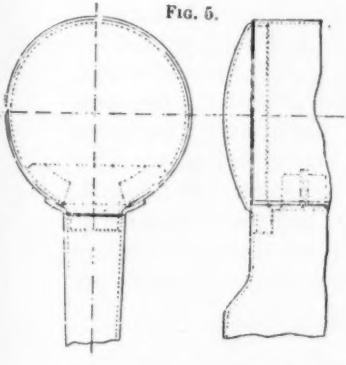
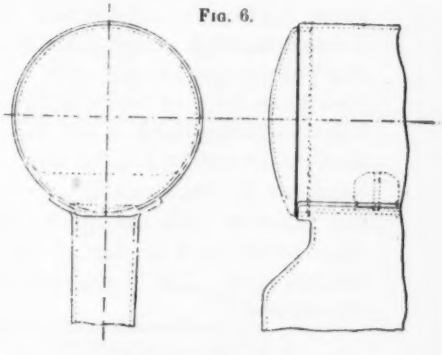


FIG. 6.



of the firm and in the Imperial shipbuilding yards at Kiel. This particular boiler is now located in the central boiler shop at Kiel, and is illustrated in Fig. 4. It represents the first Dürr boiler with its receiver placed athwartships. The tubes have already the dimensions which have since become general practice, an external diameter of 83 millimeters, and a thickness of 5 and 3 millimeters, respectively, for the lower and the upper rows of tubes. Considering its working pressure of 15 atmospheres (213 pounds), the boiler is of light build; the furnace and casing are likewise light, and the boiler weighs only 113.2 kilogrammes per square meter (23.2 pounds per square foot) of heating surface.

The boiler again shows the oblique tube ends and the lateral water wall. The tubes are, however, as in all the later types, seamless-drawn steel tubes with beaded, and no longer welded-on, ends. The rear wall is made of an annealed casting, and the superheater is joined to the receiver. Fig. 5 illustrates the junction of the round bottom of the receiver, which lies crosswise, with the water chamber. The boiler is, so to say, pushed with its bottom plates into the header. This construction was adopted on the *Victoria Louise;* the stiffening proved defective, however, and preference has been given to the flanging, which Fig. 6 explains.

The ashes collecting on the outer surfaces of the tubes were removed by means of steam jets introduced from the back of the boiler. As space is too limited for this process on board ship, it was resolved to introduce the steam jet from the front, and the stay bolts of the headers were for this purpose provided with bore holes from 15 to 18 millimeters in diameter. The bore holes are plugged when the boiler is under steam; the plugs used can be seen in Fig. 24, which we shall give later on. This boiler got up steam rapidly; it proved economical, and insensitive to forced draft and quick cooling; and the installation of Dürr boilers on a number of warships was therefore definitely decided upon. The *Baden* was the first of these vessels put into service.

THE BOILERS OF THE *BADEN*.

The boilers of the *Baden* are illustrated in Figs. 7 and 8. The Dürr Company supplied only the water chamber and the receiver; as to the other parts, the Germania Works, of Tegel, proceeded on their own lines in 1896. The tubes do not meet the header under the acute angle which is characteristic for the Dürr boiler, but project at right angles from the inclined water chamber (see Fig. 9). The thickened ends of the tubes could hence be made concentric to the axis. The tubes are carried by a cast-iron wall, which developed cracks and had to be repaired. The superheater is separated from the receiver, and is placed in the smoke box across the longitudinal boiler axis. The side rows of tubes are not approached to one another; as a result the side

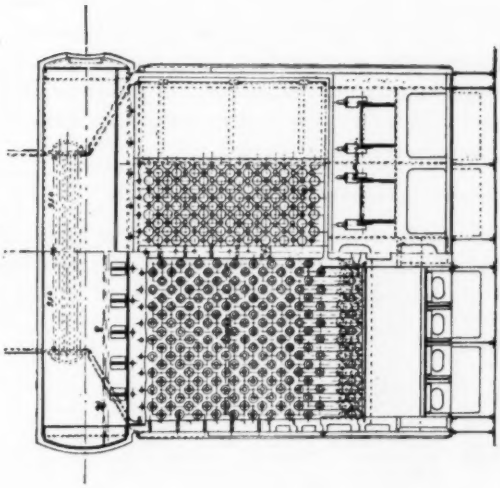


FIG. 8. BOILER OF THE "BADEN."

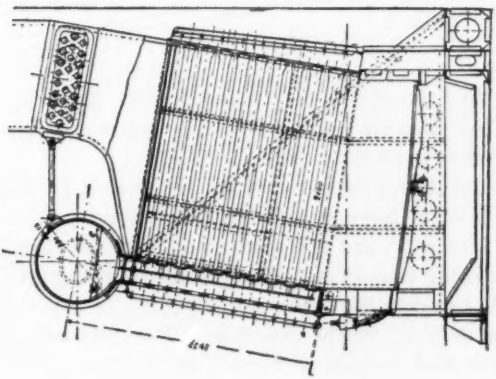


FIG. 7. BOILER OF THE "BADEN."

walls of the casing became hot. The diaphragm of the header did not close hermetically below and on the sides. The difference of pressure between the front and the rear chamber was hence diminished, and the water circulation was impaired. When these and a few other minor defects had been removed, and when the attendants had become accustomed to the peculiarity of the care of water-tube boilers, the boilers worked satisfactorily. The coal consumption is high, however.

THE BOILERS OF THE *BAYERN*.

A much more favorable account can be given of the boilers of the *Bayern*, which Messrs. Schichau, of Elbing, constructed in 1897, and illustrations of which are reproduced in Figs. 10 and

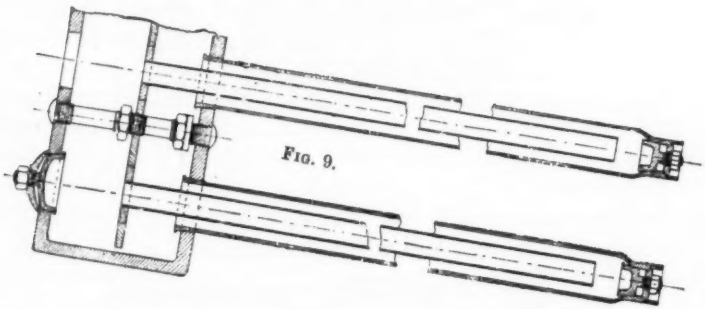
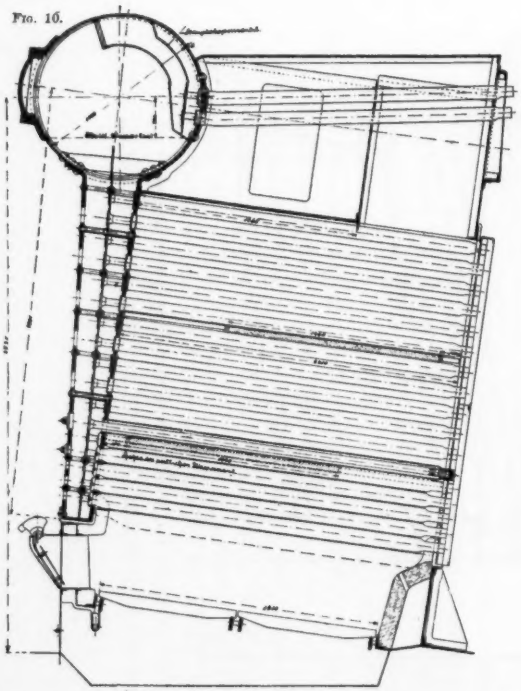


FIG. 9.

11. As they differ in several characteristic features from the Dürr boilers, they are known, not under that name, but as Schichau one-chamber boilers with Field tubes.

As in the *Baden* type, the tubes are normal to the header. The rear wall of the water chamber is, however, more inclined than the front wall, and the width of the chamber thus increases as the growing bulk of water and steam passes upwards. The back wall, carrying the tubes, is in the form of a grid of malleable iron, as in all recent examples. The connection between superheater and receiver is planned on the lines of the original Dürr boiler. On the sides the tube system is flanked by a row of wide tubes, contracted at their ends and threaded into the wall

Fig. 10.



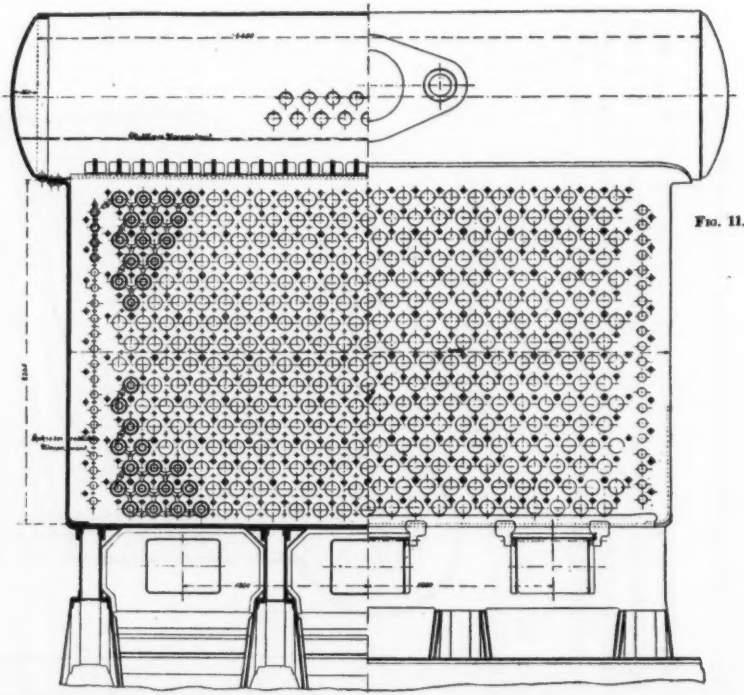
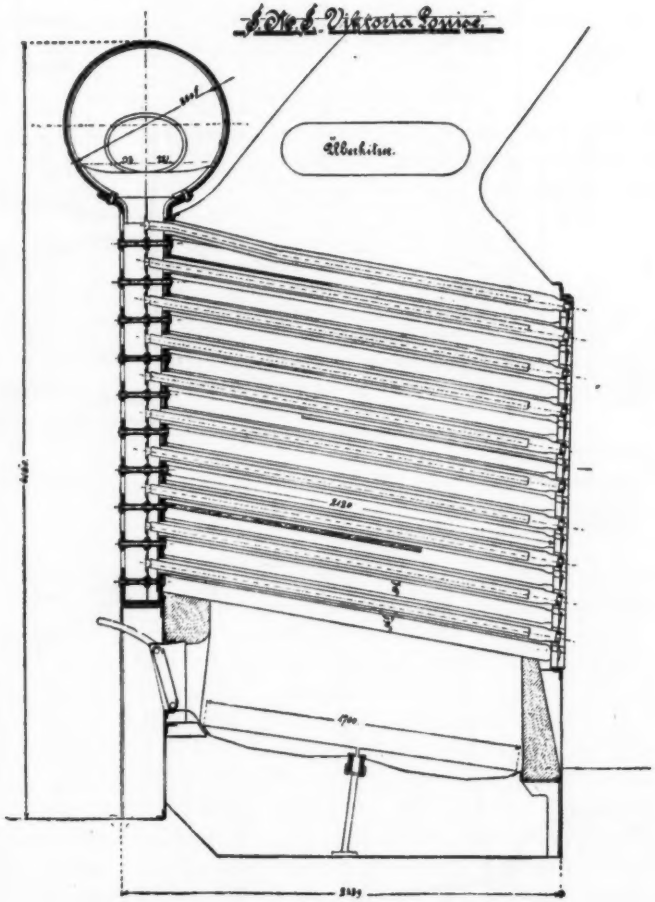


Fig. 11.

BOILERS OF THE "BAYERN."

of the header. The dimensions of the boilers are ample with respect to heating surface and power; but they are not of heavy build, for they weigh only 132.1 kilogrammes per square meter of heating surface (30.75 pounds per square foot), in spite of the

FIG. 12.



large tubes, 90 millimeters (3.54 inches) in diameter, and their large receiver, the internal diameter of which is 1,100 millimeters, against 824 millimeters (43.2 inches against 32.4 inches) in the *Baden* case. Referred to the indicated horsepower, the *Baden* and *Bayern* boilers are of equal weights.

These boilers gave satisfaction from the very first, and their coal consumption has been considerably lower than on the *Baden*, both during the trial runs and in service.

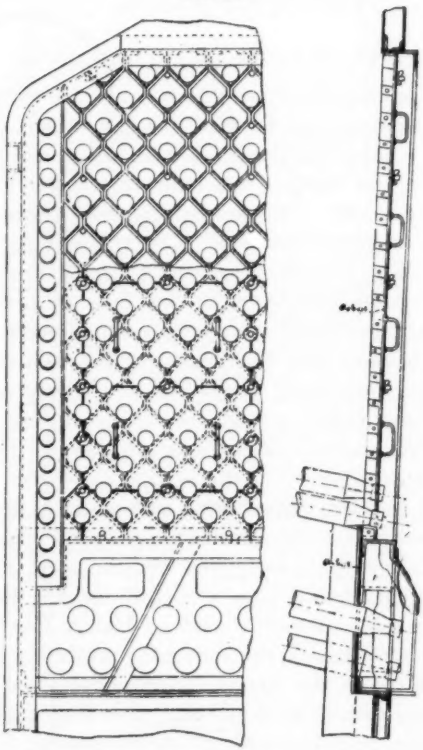
THE BOILERS OF THE *VICTORIA LOUISE*.

The twelve boilers of the *Victoria Louise* are the joint work of the Weser Company, of Bremen, and the Boiler Works, Dürr, the former making the casing, furnace and superheater according to their own designs, the latter, the boiler itself, with its tubes and rear wall. The superheater is separated from the receiver, and arranged crosswise to the tubes in the chimney, as indicated in Fig. 12; the arrangement impairs the accessibility, and leads to complications. The tube ends are again inclined to the axis, and the lateral rows are bent to form a tube wall as mentioned before. The furnace and casing have been made so light that the total boiler weight was, at the time of acceptance, only 107 kilogrammes per square meter; heating surface, 21.9 pounds per square foot. Some parts had, however, to be strengthened later on.

The tube ends are carried by a wall which is formed of bent wrought-iron rods. The construction insures great durability, and it further leaves ample clear spaces over the tube ends, through which brushes can be introduced for the purpose of cleaning the tubes on their outsides. Handy covers are applied to this lattice-work wall, the tube ends projecting through spacious apertures in the covers. These covers are to keep the flames in, and to prevent the furnace gases from entering into the space between the lattice wall and the rear casing. The arrangement can be seen in Fig. 13, which illustrates a similar boiler of the *Prinz Heinrich*. The front and rear walls of the casing are formed by corrugated plates, fixed by means of cotters, which cannot be removed and replaced without considerable trouble.

The plate joints are not tight, moreover, and allow the cold air to rush in and play about the tubes. The topmost row of tubes is bent down upon the row next below; therefore the free space between them is diminished, and the furnace gases are thus hemmed in to a certain extent.

FIG. 18.



These eight boilers, built in the year 1897, represent the pure Dürr type, no other firm having any share either in the design or in the construction. Figs. 14 and 15 are sections and an ele-

Fig. 14.

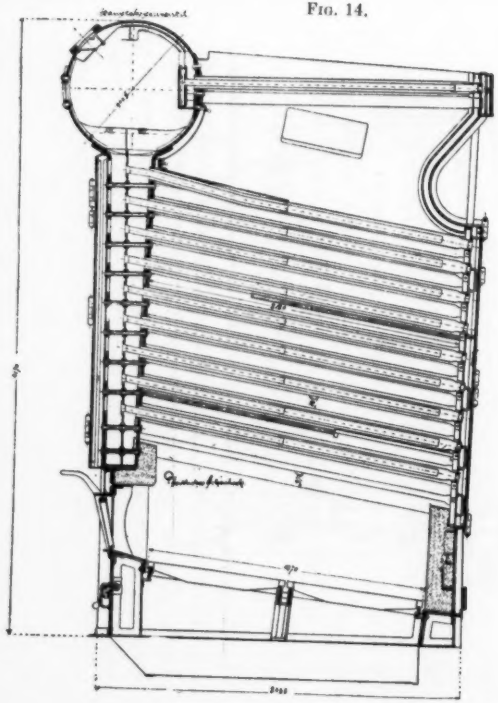
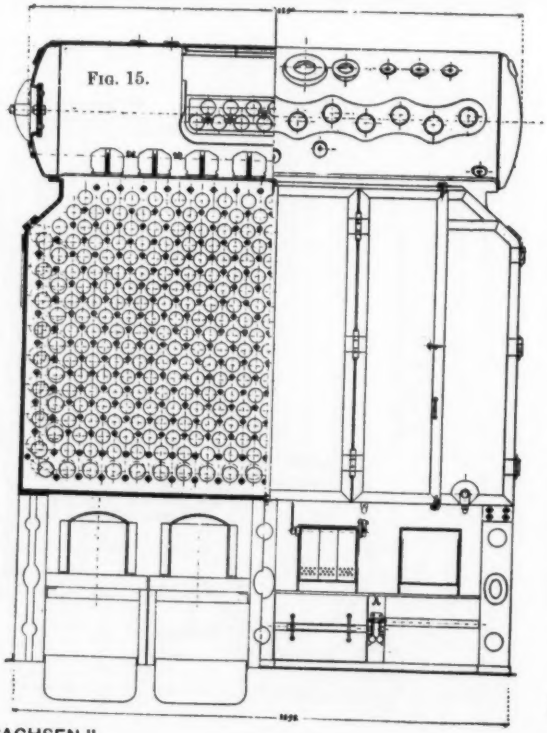
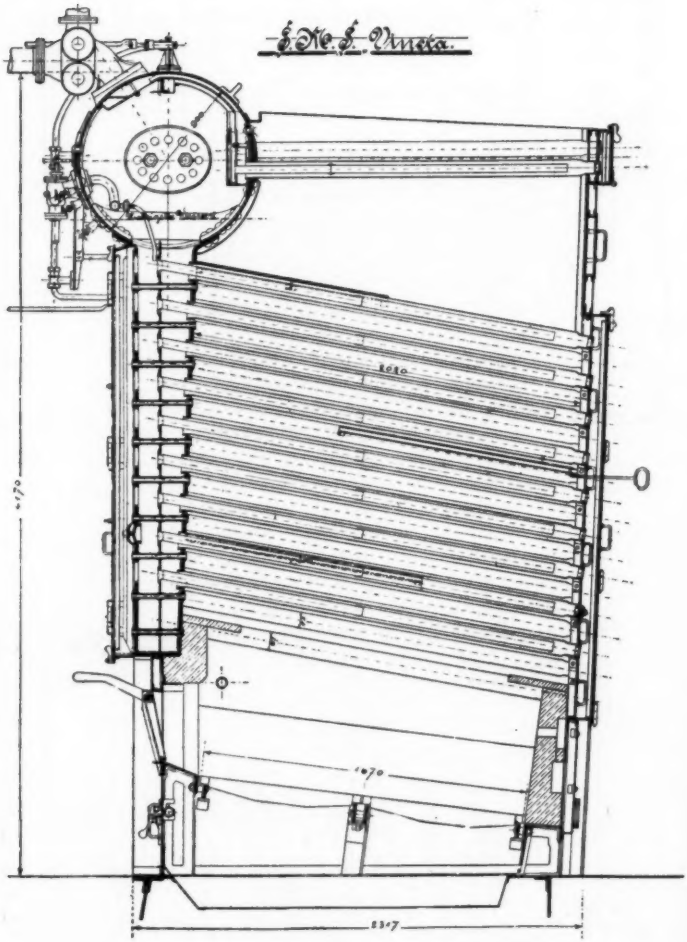


Fig. 15.



BOILERS OF THE "SACHSEN."

FIG. 16.



vation of the boilers. The inclined tube ends and the bending of the lateral rows of tubes (Fig. 15) will be noticed. The superheater is combined with the receiver. The diameter of the lowest rows of tubes, 97 millimeters (3.82 inches), with a wall thickness of 5 millimeters (0.2 inch), exceeds the customary dimension, 83 millimeters (3.27 inches), because there is a brisker evaporation in these tubes. The rear wall is built after the *Victoria Louise* pattern, already described, and is provided with the same hole covers. The front and rear casings are formed by large doors, however, which keep the dirt out more effectually without interfering with the accessibility.

THE BOILERS OF THE *VINETA*.

The large cruiser *Vineta*, a sister ship to the *Victoria Louise*, was in 1897 fitted with twelve regular Dürr boilers, which do not materially differ from those of the *Sachsen*. A vertical section of this boiler is shown in Fig. 16. The lateral tube wall has been dispensed with in order to reduce the number of different tubes. This resulted, however, in the sides of the boilers getting very hot, and radiating a considerable amount of heat into the boiler room. The top row of tubes is not bent down, as had so far been done, but is partly covered with plates, and the space between the tubes is thus narrowed. In other respects the *Sachsen* type of boiler has been adhered to. But the weight per square meter of heating surface has been reduced a little—to 125.6 kilogrammes (25.74 pounds per square foot), and the boilers further occupy less space than on the *Sachsen*. Referred to the indicated horsepower, the boiler weight is as low as on the *Victoria Louise*, although the *Vineta* boilers have a stronger casing and furnace; the *Vineta* boilers are harder worked.

THE BOILERS OF THE *PRINZ HEINRICH*.

The fourteen boilers of the large cruiser *Prinz Heinrich* again mark considerable progress. They were constructed and built by the Dürr Company, and finished in 1900. It will be seen from the sections, Figs. 17 and 18, that the dimensions have been increased. Each boiler has 284.1 square meters (3,057 square

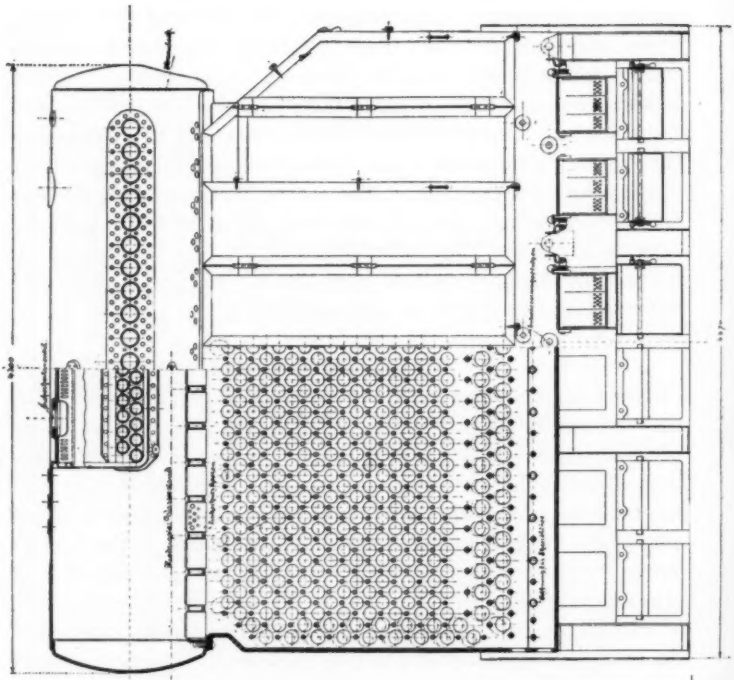


FIG. 18.

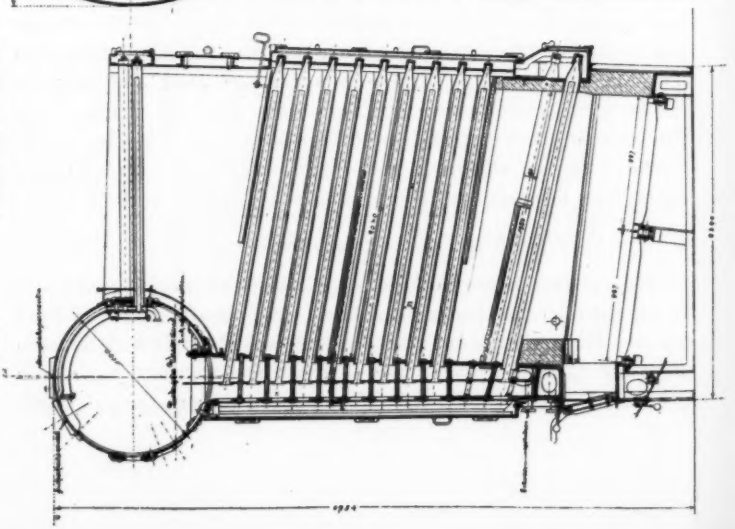


FIG. 17.

feet) of water-washed heating surface. The lateral walls, formed by crowding the tubes, have been readopted to prevent the heat losses by radiation; the receiver has a diameter of 1,100 millimeters (43.2 inches), against 900 millimeters (35.4 inches) on the *Sachsen* and *Vineta*, and a mud chamber has been added to the header, which extends deep below the lowest row of tubes. The tubes taper by a few millimeters in their cones, whose external diameters are thus reduced. Another novelty is the combustion chamber, arranged between the second and third rows of tubes, with the object of realizing a more complete combustion and diminishing the smoke. The two lowermost rows of tubes are not only larger in diameter than the others, but also more inclined in order to meet the livelier evaporation. The cap ends of the tubes, which can easily be screwed on, constitute an essential improvement, to which attention will be drawn later on.

These various improvements and the solid construction of all parts have made these boilers somewhat heavier than their predecessors; the weight amounts to 129.7 kilograms per square meter (26.6 pounds per square foot). The evaporation tests, conducted on the Imperial Wharf, at Kiel, have led to most favorable results, and have justified the adoption of many of the novel details. The trials also established the fact that the superheating on the so-called superheater does not amount to more than a few degrees (centigrade), but that the previously rather moist steam is completely dried.

THE BOILERS OF THE LARGE CRUISER *B*.

Fourteen boilers are now being completed at the Dürr works for the large cruiser *B*. They will differ from those of the *Prinz Heinrich* essentially only in one point, namely, that the additional combustion chamber has again been dispensed with, for reasons presently to be discussed. Another feature has been abandoned. The stay bolts had been made with wide bore holes, for the introduction of the steam pipes by the aid of which the adhering ashes were removed. But other methods of cleaning have been worked out. The stay bolts need no longer be hollow, and can therefore be reduced in diameter; narrower spacing

Fig. 19.

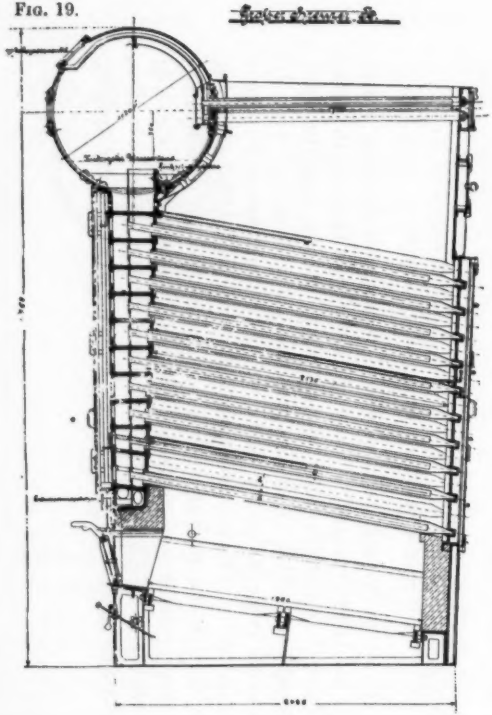
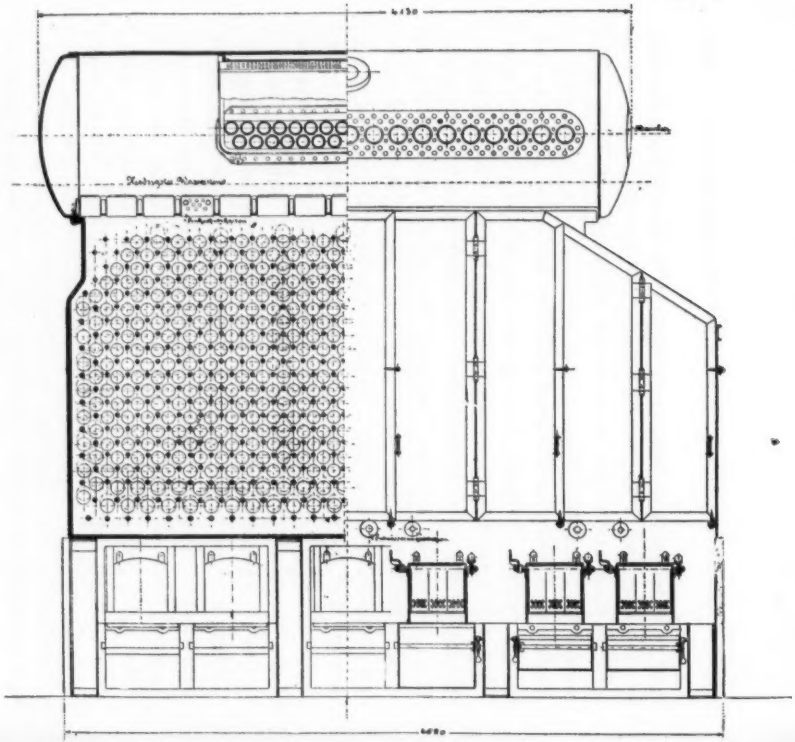


Fig. 20.



thus becomes possible, and weight and space are economized. Figs. 19 and 20 explain the general construction of the boilers as made for cruiser *B*.

CHIEF DATA OF THESE BOILERS.

The table summarizes the chief data of the boilers which have briefly been described. It gives the dimensions, weights, spaces occupied, and results of trial runs and of evaporation tests conducted on shore. The trial runs lasted six hours at forced draft. In reducing the data to the indicated horsepower unit there have been taken in consideration the powers of the main engines, and of the auxiliary machinery indispensable for the working of the engines, namely, the feed pumps, circulation pumps, and the ventilators of the stokehole. As the boiler steam is further utilized in the steering engines, other ventilators, steam cooking apparatus, &c., and for illumination, the boilers of the boats which have passed their trials perform really more than the figures of the table indicate. The two cruisers, *Prinz Heinrich* and *B*, are still at the wharves. In their cases the power has been put down as per contract. Allowance has, however, been made for steam consumption for other objects than propulsion.

The development of the Dürr boilers having been explained in its broad features, attention will be drawn to certain details.

THE QUALITY OF THE FEED WATER.

While the Dürr boilers always yield dry steam, even with sudden increases in the steam consumption, it was observed on H. M. S. *Baden*, *Victoria Louise* and *Vineta*, that the boilers primed badly as soon as only a trace of sea water contaminated the feed water, such as might gain access through a small hole eaten through a condenser tube. On the *Sachsen*, on the other hand, and on the *Bayern* likewise, up to 2 per cent. of salt have been found in the feed water without calling forth any irregular boiling. On the *Baden* and the *Vineta*, the very slightly saline water of the *Baltic* sufficed to cause priming; the *Victoria Louise* appeared to be sensitive only to the salt water of the North Sea. The latter boilers had, at any rate, always generated dry steam

when the boat was cruising in the Baltic. But as soon as the Skaw was rounded and the vessel had, on its way from Kiel to Wilhelmshaven, entered the Skagerak and the North Sea, the priming trouble commenced. It was finally ascertained that the bath water preheaters were not quite tight. The sea water got into the condensers and thence into the boilers through the return conduit of the heater steam, and it may be assumed with a fair amount of reliability that these leaks had existed already when the boat was still in the Baltic.

This severe priming rendered it impossible to run at high speeds; and as the emptying of the boiler and refilling with water then required several days of hard work, whilst the operation can now, in the recent types, be accomplished within a few hours, very serious inconvenience was experienced.

The apparently deleterious influence of sea water seems to contradict the results of experiments which Professor Gutermuth has conducted, on behalf of the Dürr firm, at the Technical College of Darmstadt. His apparatus was practically a small Dürr boiler, with only one vertical row of tubes. Professor Gutermuth reports: "No essential difference was observed in the steam generation, nor in the circulation of the water, when up to 12.2 per cent. of sea water were gradually injected into the feed water; the pressure was 7 atmospheres (100 pounds), and the steam remained dry. Addition of 0.5 per cent. of soda, however, sufficed to produce so much frothing in the receiver that priming became bad, the steam carrying a large amount of water with it." The Navy had experienced the same trouble with soda, and the difference in the two sets of observations may, perhaps, be explained by the fact that Professor Gutermuth added his sea-salt to pure feed water, whilst the boiler water on board always contains some soda. It may be that sea water causes frothing only in the presence of soda. *

At any rate, the frothing of the feed water in the presence of soda and sea water is in no way characteristic to the construction of the Dürr boiler. It finds its explanation in the physical

* These assumptions have been subsequently confirmed by later experiments.

TABLE I.—DÜRR BOILERS OF THE GERMAN NAVY.

Number.	——	Name of ship.								
		Rhein.	Experimental boiler.	*Baden.*	*Bayern.*	*Sachsen.*	*Victoria Louise.*	*Vineta.*	*Prinz Heinrich.*	Large cruiser *B.*
1	Built in	1893	1895	1896-7	1897	1897	1897-8	1897	1900	1901
2	Firm	Dürr.	Dürr.	Germania-Werft.	Schichau.	Dürr.	Dürr and Weser Co.	Dürr.	Dürr.	Dürr.
3	Number of boilers	1	1	8	8	8	12	12	14	14
	CHIEF DIMENSIONS OF A BOILER.									
4	Working pressure, kilograms	14	15	13	15	13	15	13	15	13.5
5	Grate area, square meters	3.564	5.04	6	5.27	5.08	5.22	4.64	6.75	7.4
6	Heating surface, water-washed, square meters	89.4	223.2	194	252.8	200.25	215.4	201.4	284.14	312.15
7	Ratio, grate area to heating surface	1 : 25.08	1 : 44.28	1 : 32.33	1 : 47.96	1 : 39.4	1 : 41.26	1 : 43.4	1 : 42	1 : 42.8
8	Surface of superheater tubes, square meters	3.37	18.985	cr. 8.15	9.8	11.8	16.528	11	15.69	16.42
9	Steam space in receiver, excluding superheater, cub. m.	2.3	1.61	1.48	3.79	1.79	1.304	1.68	3.23	3.51
	RESULTS OF EVAPORATION TRIALS.									
10	Coal burned per square meter of grate per hour, kg: *a*	99.2	...	...	96.46	...	86.2	...	74.96	...
	b	144.4	...	...	132.8	142.5	...	...	152.1	...
	c	200.	...	...	...	...	...	181.3	180.7	...
11	Water evaporated per hour per kilogram of coal, reduced to steam pressure of one kilogram and feed-water of 0 degrees Centigrade: *a*	7.922	...	...	8.524	...	9.37	...	9.125	...
	b	7.811	...	...	8.174	8.10	...	...	8.227	...
	c	7.703	...	...	...	...	...	7.54	7.711	...

TABLE I.—DÜRR BOILERS OF THE GERMAN NAVY.—Continued.

Number.			Name of ship.								
			Rhein.	Experimental boiler.	*Baden.*	*Bayern.*	*Sachsen.*	*Victoria Louise.*	*Vineta.*	*Prinz Heinrich.*	Large cruiser *B.*
		RESULTS OF TRIAL RUNS.									
12	Six hours' trial run at forced draft.	Power indicated main engines and auxiliary engine machinery, I.H.P	350	...	6,355	6,555.93	6,606.9	11,042.9	11,012.7	As by contract. 15,600	As by contract. 18,000
13		Power per sq. meter of heating surface I.H.P.	3.91	...	4.09	3.24	4.12	4.27	4.55	3.92	4.11
14		Coal per sq. meter of grate area, kg	99.05	...	135.6	134.2*	162*	175*	200*	165*	1,775*
15		Coal per I.H.P. per hour, kg	1.09	...	.969	.83*	.84*	.9*	.96*	...	...
16		Air pressure in stokehole, mm. of water	...	...	34.14	34.14	14.925	28.6	35.9	...	...
17	24 hours' full steam run.	Power of main engines and auxiliary engine machinery, I.H.P.	...	...	4,704.5	4,652.946	4,686.7	6,261	...	...	...
18		Power per square meter of heating surface, I.H.P.	...	...	3.03	2.3	2.92	2.42	...	...	...
19		Coal burned per square meter of grate area, kg	...	...	95.8	83.907	115.52	93.6	...	...	...
20		Coal per indicated horse-power per hour, kg	...	...	.897	.70	.906	.892	...	...	...
21		Air pressure in stokehole, millimeters of water	...	...	27.65	6.125	12.7	3.5	...	...	...

*Approximate.

22	24 hours' run.	Power of main engines and auxiliary engine machinery, I.H.P.	...	...	1,365	1,317.52	...	1,269	1,202.8	...	...
23		Power per square meter of heating surface, I.H.P.	...	...	1.76	1.35	...	1.47	1.19	...	...
24		Coal burned per square meter of grate area, kg.	...	...	73.45	68.368	...	68	64.77	...	...
25		Coal per indicated horsepower per hour, kg.	...	...	1.041	.844	...	.834	.934	...	...
26		Air pressure in stokehole, millimeters of water	...	...	9.75	0	...	0	0	...	...
		Weight of a Boiler.									
27		Weight of boiler body with superheater, kilograms	...	12,536	22,017.2	18,890.8	15,848.25	13,741	14,252.75	29,353.6	31,043 projected.
28		Weight of coarse fittings, grate, and brickwork, kilograms	...	4,247	5,541.25	6,883.8	4,744.3	3,398.3	5,198.6		
29		Weight of boiler casing, kilograms	...	3,327	380.75	1,143.4	412.75	1,096.8	855.9		
30		Weight of water, kilograms	3,610	5,150	4,261.75	6,530	5,500	4,813	5,000	7,500	7,700
31		Weight, total, kilograms	21,565	25,260	32,200.95	33,418	26,505.3	23,049.1	25,307.25	36,853.6	38,743
32		Total weight per square meter of heating surface, kilograms	241.2	113.2	165.9	132.1	132.3	107	125.64	129.7	124.11
33		Total weight per indicated horsepower, kilograms	61.61	...	40.5	40.7	32.09	25.04	27.57	33.07	30.13
34		Water weight per indicated horsepower, kilograms	10.3	...	5.4	7.93	6.65	5.23	5.44	6.73	5.98
		Spaces Occupied by Boiler.									
35		Floor space, square meters	6.85	8.66	9.25	11	8.01	8.52	7.77	10.42	11.2
36		Height from floor to upper edge of receiver, meters	4.165	4.3	4.4	4.36	4.17	4.16	4.17	4.56	4.565
37		Floor space per indicated horsepower, square meters	.0196	...	.0116	.0134	.0097	.0092	.0084	.0093	.0087
38		Floor space per square meter of heating surface, sq. m	.0766	.0379	.047	.043	.04	.039	.038	.0366	.0358

properties of the water, and would result in all types of boilers, though it would not always prove equally disturbing. The less water we have in a boiler the quicker the saturation conducive to frothing will be reached; the smaller the bubbling surface the higher the water will spurt, and the closer the entrance to the superheater is to the water surface the more water will be carried over into the engine. For these reasons the receivers and the sections of the crossheaders have been enlarged in the recent modifications of the boilers.

TABLE II.—STEAM SPACES AND SECTIONS OF HEADERS.

Boilers.	Receiver.			Steam space in receiver.		Rear half of header.			Ratio of volume of steam generated per second to sectional area of rear part of header.
	Internal diameter.	Length of shell.	Height above water level, internal.	Total capacity.	Per square meter, heating surface.	Length.	Width above.	Cross section above.	
	mm.	*mm.*	*mm.*	*cb. m.*	*liters.*	*mm.*	*mm.*	*sq. m.*	
Experimental boiler	900	2,683	750	1.61	7.2	2,715	156	0.48	0.596*
H. M. S. *Baden*	824	3,644	592	1.48	7.6	3,374	98	0.33	0.724
H. M. S. *Bayern*	1,100	4,460	830	3.79	14.9	4,020	170	0.683	0.318
H. M. S. *Sachsen*	900	3,000	750	1.79	8.9	2,792	167	0.466	0.592
H. M. S. *Victoria Louise*	850	2,490	725	1.304	6.0	2,621	121	0.317	0.77
H. M. S. *Vineta*	900	2,800	750	1.68	8.3	2,590	166	0.429	0.641
H. M. S. *Prinz Heinrich*	1,100	3,960	800	3.23	11.4	3,730	184	0.686	0.430
H. M. large cruiser *B.*	1,150	3,700	800	3.51	11.24	3,450	184	0.634	0.589

* Evaporation eightfold.

The dimensions of the water and steam spaces of the several boilers will be found in Table II. This table enables us to convince ourselves that the ships named, which were liable to priming, had been fitted with small receivers, and, considering the volumes of water and steam to be generated, comparatively narrow water chambers. The relations were manifestly more proportionate in the *Sachsen* and *Bayern* boilers, and in these, as has

been stated, the admixture of 2 per cent. of salt did not do any harm. The ratios given in the last column of Table 11, namely, the volume of steam passing per second through the rear of water header, compared with this cross section of that header, has been calculated under the assumption that dry steam is rising, and not, as is the case in reality, a mixture of steam and water. This assumption appears justified, as the figures are quoted only for their comparative value. The steam consumption has been estimated at 7.5 kilogrammes per indicated horsepower. (The equivalent would be 16 pounds, neglecting the difference between British and Continental horsepower.)

From what has been discussed, it may be hoped that the most serious objection to the Dürr boiler under which the early specimens labored, namely, the sensitiveness to contamination with sea water, will not affect—or affect to a slight degree only—the recent types of those boilers. When Dürr boilers are charged with well water, or ordinary supply water, no priming is observed. This has been demonstrated by many experiments, and recently again during the evaporation trials of the *Prinz Heinrich*. The boiler was fed with the muddy water of the Keil shipbuilding yard, which deposits a considerable amount of scale, and the steam was always dry, even when the draft was forced to its maximum. While, however, on stationary Dürr boilers and Dürr boilers for river boats most of the mud and the scale settle in the rear portion of the receivers, which on these boats are disposed longitudinally, all the impurities of the naval boilers, with receivers athwartship, collect in the water chamber and in the internal tubes. When, therefore, naval Dürr boilers have to be fed with well water, the internal tubes will have to be cleaned at comparatively frequent intervals, and it will be advisable not to use any but distilled water. It should be pointed out in this place that all parts of the Dürr boilers can easily be freed of incrustations.

THE WATER CIRCULATION.

The circulation of the water and the evaporation in single tubes have been studied by Professor Gutermuth in connection with the

tests already alluded to, the motion of the steam and water being watched through windows and measured in different portions of the tubes and of the water chamber. The results of these researches are graphically represented in Fig. 21. The evaporation curves *A* and *B* were obtained with the tube arrangements illustrated in Figs. 22 and 23, and they show at a glance how very

FIG. 21.

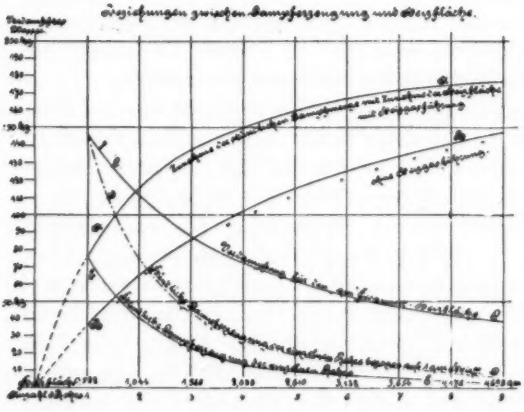


FIG. 22. FIG. 23.

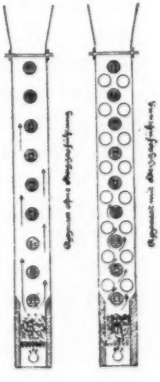
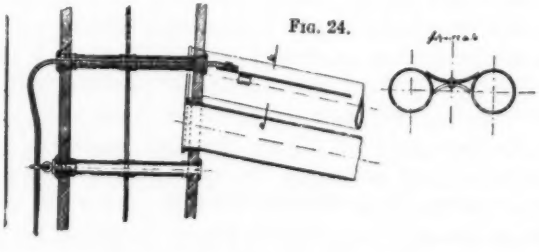


FIG. 24.



much better the heat in the furnace gases was utilized when baffle plates forced the gases to ascend in a zigzag course than when they simply passed by the tubes in vertical currents. The curves *C*, *D*, *E*, demonstrate that the evaporation proceeds much

more briskly in the lower rows of tubes than in the higher rows, and that it was a step in the right direction to enlarge the diameters of the two lower rows as regards the water circulation. Professor Gutermuth comes to the following conclusion:

"The results of the tests made with the experimental Dürr boiler show that, with clean heating surfaces free from ashes, a steam generation of 40 kilograms per square meter heating surface (8.2 pounds per square foot) should well be realizable per hour."

In the tests of the *Prinz Heinrich* boilers, 33 kilograms of steam was the maximum value obtained. This lower value may be ascribed in the first instance to the circumstance that Professor Gütermuth used coke as fuel. It is further to be borne in mind that the evaporation will not be so lively in the lateral as in the central tubes.

"With normal tubes, the water circulation remains, under all working conditions, sufficiently active and regular to obviate any dangerous baring of the tube walls of water and any lasting deformation of the tubes. No choking of steam was observed in the lowest tubes in which the evaporation is most lively, even when the steam consumption fluctuated considerably. It was always observed with a varying steam consumption that the upper portions of the tube walls were washed by the water which the steam carried with it. From the comparative tests to which this experimental boiler and a Dürr boiler in regular operation in the Dürr works were submitted, it may be derived that the conclusions drawn from the behavior of the experimental boiler will be applicable to Dürr boilers in general."

It should be mentioned that the baffle plates placed upon some of the rows of tubes in the actual boilers, which baffle plates guide the furnace gases in the manner indicated in Fig. 23, obliquely to the tube axes, were absent in the experimental apparatus. The baffle plates are advantageous in one respect, inasmuch as they lengthen the contact between the hot gases and the tubes. Their disadvantage is that they produce dead corners.

DISPOSITION OF BOILER ON BOARD.

Professor Gutermuth has also investigated the problem of the influence of the inclination of the tubes on the water circulation. The experimental apparatus was for this purpose lifted at its rear end until the slope of the tubes was only 1 millimeter in 150 millimeters of tube length. "With a regular steam consumption, a perfectly uniform water circulation could still be maintained, and no trapping of steam bubbles was noticed. Even when the steam consumption was suddenly varied, the disturbances in the movements of water and steam proved of little consequence; large steam bubbles were temporarily observed at the rear ends of the lowermost tubes. The bulk in circulation did not materially differ from that observed with normal tube inclination." Similar experiments had been conducted in the Kiel shipbuilding yards, in 1896. It was then ascertained that no disturbance resulted as long as the inclination was not reduced to less than 1 degree below the horizontal; when the tubes were slanting in the opposite sense, all water circulation stopped when 1 degree above the horizontal was exceeded.

Since the rapidity of the water circulation depends essentially upon the pressure difference in the front and the rear water chamber, the inclination of the tubes should, indeed, not much matter, provided that the steam bubbles can still escape. The increased friction which the steam bubbles undergo when the inclination is diminished should not exercise any material influence within the limits of inclination of 10 degrees and 1 degree below the horizontal. The Navy must, however, insist that the boilers of a ship continue to operate when the damaged boat takes a list of 15 degrees. Since the tubes, apart from the lower rows, for which a larger inclination is adopted, slant under an angle of 10 degrees only, it is manifest that the tubes of a Dürr boiler most not lie athwartships. When the tubes are disposed in the fore-and-aft line the worst pitching and the greatest changes in the trim are not likely to interfere seriously with the water circulation. For on a boat of 100 meters length the stern would have to project or to be immersed by 7.5 meters before any disturbance could arise.

FURNACE GAS CIRCULATION.

In order to effect a uniform distribution of the combustion gases, and to prevent their sweeping through the tube system at too rapid a rate, the tubes of the top row had been bent downwards towards the tubes next below, and flat firebricks had been placed on the lowermost and one of the middle rows of the tubes, for certain distances. This was done in the experimental boiler, and tried also on the *Victoria Louise;* but it did not answer. The furnace divisions were deficient in height, and the lower tubes became too hot. On the *Sachsen*, then, the firebricks were applied to the fourth row, and not to the lowest; the bricks extended in unbroken series over the front two-thirds of the tube length, whilst originally free spaces had been left between the different bricks, so as to force the gas to traverse the tube system in zigzag paths. The bending down of the top row of tubes was adhered to for the time. A similar arrangement was adopted on the *Bayern*. (The bricks are marked in Fig. 4.) On the *Vineta*, this bending down of the tubes was abandoned, and the clear space between the upper tubes was reduced by means of cover plates. The good services rendered by baffle plates also in the lower rows of tubes had meanwhile been established by other naval investigators. The small firebricks were hence replaced by sheet-metal plates, 4 millimeters ($\frac{1}{6}$ inch) in thickness, applied to the fifth and twelfth rows of tubes. The shape of these plates is shown in Fig. 24; the shaking device, likewise illustrated by that diagram, will be explained later on.

The firebricks had been heavy, and, being of a peculiar shape, they were difficult to obtain when the ship was abroad; their abandonment was hence advantageous in several respects. Firebricks were, however, retained on the *Vineta* for the extremities of the lowermost tube, in order to protect the cones and the rear wall from the flames. Further use of firebricks was again made on the *Prinz Heinrich*. As mentioned, and as shown by Figs. 17 and 18, the tubes were on these boilers disposed in a special manner, and firebricks were laid so as to create a special combustion chamber between the second and third rows of tubes. A high temperature was aimed at for this chamber, and preference,

therefore, was given to firebricks. In this chamber a thorough mixture of the gases was to take place, and sufficient space was provided to allow of a complete combustion, with the further object of keeping the smoke down.

For experimental purposes, such chambers had been formed in two boilers of the *Sachsen* by removing the third, fourth and fifth rows of tubes. Analyses of the furnace gases proved that a more complete combustion was realized; there was no noteworthy diminution of the smoke, however. The evaporation tests of the *Prinz Heinrich* boilers, and their gas analyses, also pointed to a good combustion. The trials with forced draft further gave remarkably little smoke. A test with natural draft, however, during which only 75 kilogrammes of coal were burned per square meter (15.4 pounds per square foot) of grate area, yielded as much smoke as if there was not draft enough to force the gases in their zigzag path through the bundles of tubes. The utility of the special combustion chamber thus appeared at least doubtful. Such chambers add to the weight, claim space, and render the cleaning of the boiler more difficult. The boilers of the large cruiser *B* have therefore been designed without combustion chambers, and no special firebricks will be wanted for guiding the furnace gases.

FIRE DOORS AND ASH TRAPS.

As the fire doors of the early boilers did not meet all requirements, and necessitated rather frequent repairs, especial regard was paid to their design and construction on the *Prinz Heinrich*, as illustrated in Fig. 25, which embodies various improvements that had suggested themselves. The doors are strong in all parts, and the double walls are cooled by a powerful current of air which passes upward. The inner protective shield is easily exchangeable. A friction-grip pawl engaging in a V groove in a wheel fixed on one of the axes of the door holds the door in any position; it dispenses with the heavy counterweights elsewhere employed, and is an improvement on the ratchet wheels which had first been tried. The originator of this gearing is machinist Horst, of the *Sachsen*; it was, in autumn 1899, adopted

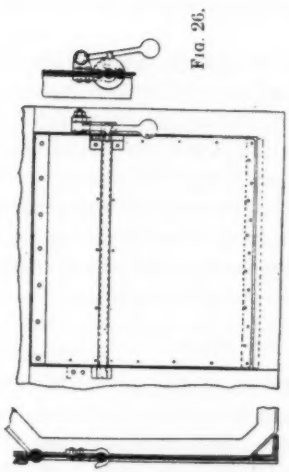


Fig. 26.

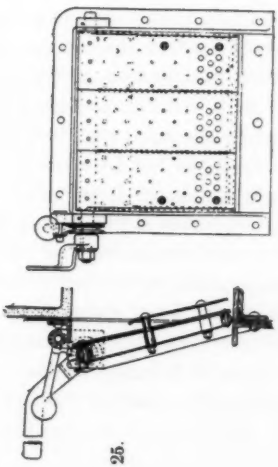


Fig. 25.

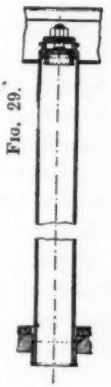


Fig. 29.

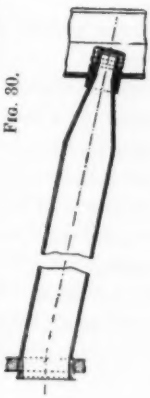


Fig. 30.

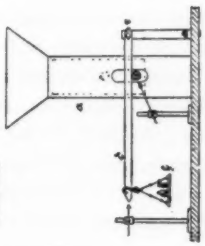


Fig. 28.

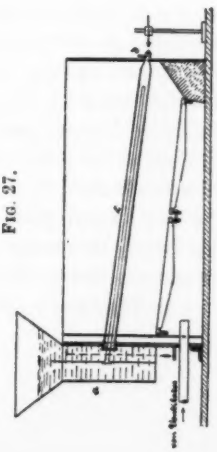


Fig. 27.

on all the boilers of the *Sachsen*, and continues to give complete satisfaction.

Mention should also be made of the ash-pit doors of the *Prinz Heinrich*, of which Fig. 26 gives an idea. The doors turn about an axis, situated at about one-third the height from above, and they are balanced by two semi-cylindrical irons riveted to the upper edge. The area of the lower portion of the door being larger, the draft tends to turn the upper weighted edge outward; the pawl marked in the diagram permits of fixing the trap in any position. If the boilers should be damaged, the steam rushing into the ash pit would automatically close the doors.

BUCKLING OF THE TUBES.

Some stir was caused during the early days of the Dürr boilers, when it was noticed that the lower tubes tended to curve upwards, instead of sagging, as might have been expected. Figs. 27 and 28 are diagrams of a special apparatus which the Dürr firm devised for investigating this peculiarity. The apparatus consists of a water chamber *a*, open above, fixed to a vertical wall, and holding a boiler tube *c* of the usual dimensions, 83 millimeters internal diameter and walls 3 millimeters thick (3.27 inches and 0.12 inch) freely swinging at its far end. The grate and furnace were entirely independent of the boiler and tube, lest any expansion of their parts should affect the tube. The boiler was charged with water. When the fire was started, the free tube extremity began to rise; with full furnace glow the rise amounted to 10 millimeters; when the tube had cooled, it proved straight again. The tube was now lined on its inside with a thickness of 2 or 2.5 millimeters (about $\frac{1}{12}$ inch) of cement, filled with water, and kept for two hours at full heat. The tube did not suffer noticeably, but the deflection, the rise, of the tube end amounted to as much as 44 millimeters ($1\frac{3}{4}$ inches), and the rise varied with the state of the fire. Every time on fresh stoking it decreased to 7 millimeters, to rise again to 40 or 44 millimeters, finally showed an upward bending of the cold tube 1.5 millimeters. Experiments with another somewhat

stouter tube, 5 millimeters in wall thickness, led to analogous results.

Further, to inquire into the matter, the balance device of Fig. 28, not applied so far, was put to use. It consists of a lever *d*, pivoted at *e*, bearing a scale pan *j*, for the reception of weights at its free end, and resting on the tube end. It was ascertained that to prevent the free tube end from traveling upward, required in the experiment with the cement-lined tube just mentioned, at full glow a load of from 37.5 to 42.5 kilogrammes, roughly 90 pounds. During stoking the load needed to keep the tube straight went down to 0. After two or three hours of firing the re-cooled tube remained curved upward by 2 or 3 millimeters.

This abstract of the tests demonstrates that during firing the tube exposed to the hot flames bends downward, and this the more, the less the tube-half turned towards the fire is cooled by the water. The lower half becomes considerably hotter than the upper half, and the difference of temperatures leads to a curving downward of the tube. After cooling, however, the tube displays a curving upward, especially when high temperature had been applied, the lower tube half becoming nearly red-hot. This upward curving is explained as follows: The lower half of the tube which is exposed to the direct flame cannot, without restriction, expand as it would in accordance with its temperature. It has either to stretch the upper cooler half beyond the temperature conditions of that upper half, or it will itself be checked in its expansion, and will, at red heat, not be able to expand to the full extent. When during this process the limit of elasticity is exceeded, the lower half must, after cooling, be shorter than the upper, and hence an upward curving must result. When now the free end of the tube is prevented, by its attachments, from traveling upward, then that free end will, on account of its being fixed, undergo a downward pressure which will cause a further stretching of the upper half of the tube and a compression of the lower. The permanent curving upward will, therefore, be more pronounced than when the rear extremity of the tube is free to move.

Other circumstances may contribute to modify the curving of the tubes, such as internal stresses in the material, one-sided heating in the case of the lateral tubes, interference with the free longitudinal expansion, etc. It is not rarely found on board that tubes in proximity to one another are bent in entirely different ways. We may thus assume that a slight buckling of the tubes is in accordance with physical laws, and does not either indicate defective water circulation or internal clogging, or prevention of the free movement of the tube end.

No importance need, hence, be attached to a slight curving of the tubes, especially when it develops at the beginning of a new period of working. If a particular tube becomes noticeably bent during regular service, we may think of internal clogging with mud. If a tube has so badly curved that contact between the inner wall of the tube and the outer wall of the internal tube must be feared, a case which is rare unless with very dirty boilers, that tube will have to be taken out and straightened in the screw press which is kept on board ship. It has been established on the Imperial wharfs at Kiel that this rebending does not materially impair the strength of the tube.

In order to keep the internal tubes well concentric, even when the outer tube begins to curve, the internal tubes of the *Sachsen* are centered by three springs, both near the ends of the internal tube, where their use is customary, and at half length. This arrangement has proved useful, and will be adopted on the other ships of the Navy.

INSENSITIVENESS OF THE BOILERS.

The Dürr boilers are remarkably little sensitive to rapid heating and cooling, forced draught and cold-air blasts, and this must be considered a great point in their favor. Mud and grease, when accidentally carried into the boiler, generally collect in the water chamber or its special mud channel. They may also get into the internal tubes, where they will do no harm as long as they do not stop the water circulation. A tube in which mud and grease have badly accumulated will, as a rule, only curve more than the others without springing a leak in the cone.

Tubes will not be burned unless for want of water and when very dirty during long periods.

The want of sensitiveness to a temporary deficiency of water is illustrated by a case which would most probably have had serious consequences on a vessel with cylindrical boilers. The water-gages failed to do their duty. The Dürr boiler tubes had become redhot up to the upper rows, and had curved noticeably; but there was no leakage anywhere. The tubes were taken out, straightened, and put in again. Within twelve days of ten hours the boilers were restored to working order. This was accomplished with the aid of the outfit of the shipbuilding yards at Kiel, it must be stated. On board, the repair might have occupied more time, as the hand presses there available for straightening the tubes do not work with the speed of the hydraulic presses of the yard.

THE ATTENDANCE OF THE FIRES.

Owing to the small water capacity of tubulous boilers, the quantity of heat stored in them is rather small; and any diminution in the temperature, consequent upon putting on fresh coal or keeping the fire doors open, indicates itself at once as a fall in the steam pressure. It appears, therefore, advisable to keep the fires thin, and to stoke more frequently and less liberally than is customary with cylindrical and locomotive boilers. When this rule is observed, coal is economized, and bad smoking is avoided. The attendants of Dürr boilers are consequently instructed to keep thin fires of 10 or 12 centimeters (4 or 5 inches), and to renew the fuel at frequent regular intervals, and to look after the different boilers in due sequence. The coal charge is fixed at about 8 kilogrammes per square meter (1.6 pounds per square foot) at each firing.

In order to secure a proper observation of these rules and to accustom the stokers to maintain uniform thin fires, electric bells have been put up in all the stokeholes, and these are set in motion at regular intervals of about every 2, 2½, 3 or 4 minutes by the so-called stoking clock of the engine room. At each bell signal half the number of fire doors must be attended to, and a certain bulk of fuel be put on. The intervals at which the fires have to

be seen to at various speeds have been calculated for each ship, and if the speed is afterwards to be increased the additional fuel charge is easily distributed in a uniform manner over the several grates by adjusting the stoking clock, which will then give its signals at a quicker rate. This method of stoking has. once understood, not caused any difficulties. The task of the stokers is, of course, rendered harder since their periods of rest are shortened. On the other hand, the actual exertion is materially lessened, for a thin layer of coal is much more easily managed than a locomotive fire, where 30 or 40 centimeters (12 or 16 inches) of coal have to be dealt with.

For the proper operation of the Dürr boilers, this method of stoking is, moreover, by no means indispensable. With suitable regular stoking, the fluctuations on the steam pressure disappear; but that applies to all other types of boilers, and there will be a saving in the coal bill and less bother with the smoke, as in other cases.

THE EXTERIOR CLEANING OF THE BOILERS.

A considerable amount of ashes settles on the baffle plates. The deposit may reach a height of 40 centimeters (16 inches) and more, even in a few days, and the ashes may entirely surround the four or five rows of tubes over those baffle plates, to the detriment of the boiler efficiency. It was hence feared that the fuel consumption would rise more and more on long voyages, owing to this clogging up of the tubes with ashes. Fortunately, the experience gained on the *Sachsen* does not confirm this apprehension.

The original instructions by the Dürr Company recommended that the ash crust should be washed off the tubes by means of steam jets, introduced through the stay bolts which were bored for this purpose. This method proved very troublesome and fatiguing in the narrow stokeholes, and occupied much time without being efficacious; for the ashes were rather stirred up than removed. Steam injection was therefore given up, and the following process was first adopted on the *Sachsen* and on the *Vineta*, after cutting out the respective boilers.

The covers on the rear lattice wall of the boiler are removed,

the back doors opened one after the other, and the ash traps and trap doors in the chimney shell are closed, whilst the funnel damper is opened. A pressure of two inches of water is then produced in the boiler room with the aid of the blowers. The sharp draft thus generated drives all the ashes which have settled in the boiler through the funnel into the air. Such a cleaning is done on the *Sachsen* by a non-commissioned officer and five men within half an hour; the job is thorough, and the stokehole is not badly dirtied. The funnel and funnel neck get a good cleaning at the same time. The other boilers in operation in the same room are not disturbed by the high air pressure if care be taken to adjust their ash-pit doors. The cleaning on the *Sachsen* was a very tough piece of work, because the ashes cake so firmly on the system of baffle firebricks that they must first be loosened with rods. On the fourth row of tubes the firebricks come up to the water chamber. As the air pressure forces the ashes against the rear wall of the header under these circumstances, it is necessary first to push the firebricks back.

With the replacement of the firebricks by sheet metal, first applied on the *Vineta*, this trouble ceased. As Fig. 24 shows, the baffle plates have, by the Kiel wharfs, been joined to stiff wire ropes, which are taken through the hollow stay bolts. With the help of these ropes the plates are rigorously shaken, so that the ashes are loosened and begin to fall, to be carried away by the powerful draft. The addition of this device has rendered it possible to effect a rapid and fairly thorough cleaning with the simultaneous aid of a good ventilation, without stopping the steam generation.

On the *Prinz Heinrich* the baffle plates are agitated with the aid of iron rods. The rods, serving the plates adjoining the headers, are again taken through the hollow stay bolts, and are joined in front of the header, to be out of the way of the doors.

When these boilers were being built steam injection was still resorted to for cleaning, and the stay bolts were hence bored through. In the boilers for the large cruiser *B*, only those stay bolts are being made hollow through which the agitator rods will have to be passed.

The *Prinz Heinrich* is the boat on which a special combustion chamber was provided by putting in a system of firebricks. To get the ashes off these bricks trap doors have been inserted in the rear wall of the boiler. This difficulty will no longer arise on the cruiser *B*, for all the baffle plates can be shaken, and firebricks have entirely been done away with.

The slimy soot which sometimes settles on the lower rows of tubes, and which is detrimental to the heat transmission, cannot be blown off; it has to be scraped off after extinguishing the fires.

CHANGE OF WATER AND INTERIOR CLEANING.

In spite of the exclusive use of distilled water the boiler water will gradually become contaminated with oil, sea water, soda, sediments from the protective zinc plates, etc. After about 300 hours' service, the water should be renewed. Blowing off can, however, only remove the water contained in the header—about a quarter of the whole bulk; the water in the tubes will remain there. To remove the conical caps of the tube ends, illustrated in Fig. 9 and in Fig. 29, was considered inadvisable in the early days. It was thus necessary to take down all the front covers opposite the tubes, which meant, on the *Vineta*, taking down no fewer than 372 covers in each of the eight boilers, draw out the internal tubes, and empty the tubes by means of syphons.

On the *Sachsen* it was first tried to effect the emptying of the tubes by loosening and pushing back the conical plugs. But with the construction of the conical ends, then in use, some water and mud would always remain in the tube, and there was further trouble because a little mud would get between the conical faces.

Both the Imperial Navy and the Dürr Works were therefore striving to design a tube-closing device which would permit of thoroughly emptying and scouring the tubes from the rear. After many experiments with rows of tubes of the *Victoria Louise*, the *Bayern* and the *Sachsen*, the device illustrated in Fig. 30, first applied on the *Prinz Heinrich*, has been selected as the most practical. The tube ends taper conically, and are provided with a thread; on this thread is screwed a cap of bronze. The shape of the tube extremity allows all the water to flow out. An iron

collar is screwed permanently on the tube, and this collar serves two purposes: it forms a packing for the cap and a guide for the tube in the rear wall of lattice structure. The conical ends have also been adopted for the tubes of the superheater, although the latter, which lie horizontal, need not be emptied from the rear. Fig. 29 is a diagram of one of the superheater tubes of the *Prinz Heinrich*.

The caps are made of a manganese-bronze, supplied by the Isabellenhütte, of Duisburg. The material was selected on the basis of careful experiments as possessing the greatest strength at the high temperature of 500 degrees centigrade (932 degrees Fahrenheit). Threaded iron caps have been employed on the modified tube ends of the *Sachsen*. Their use has, however, not been continued, as it was feared that the irons would rust and stick with their threads on the conical ends. Later experience has justified these fears.

When the cap is removed, the whole of the water contained in the tube flows out in a good stream, and the tube is scoured of most of its mud, especially if the water was still warm. If necessary, a further scouring by means of water jets can be applied from the rear. The drawbacks of this method of cleaning are that the boiler room is fouled by the water and that the refixing of the caps has to be performed with a certain amount of care. The threads of the tubes and caps are cut to gages, so that every nut fits on every tube.

During the evaporation tests with the boilers of the *Prinz Heinrich*, which have 543 tubes, the water was renewed in the manner explained by four men in six hours. The old method, which necessitated the removal of the covers and the application of syphons, would have taken about six days.

These improvements in the tube ends, which obviate the necessity of opening doors, withdrawing the internal tubes, and introducing syphons, for the purpose of changing the water and scouring the tubes, have simplified the care of the boilers to a remarkable degree. One or two thorough cleanings, with removal of the covers, will now suffice for a year.

A partial cleaning of the bottom of the water chamber and of

the lower tubes, and some other tubes which are most liable to become clogged with mud, will still be necessary on more frequent occasions. The intervals that may elapse between these partial cleanings vary for the various ships, because the oil consumption, the quality of the feed water, and other circumstances come into play. The intervals will be shorter on ships under trial, where all parts of the machinery have to be liberally lubricated, and where the *personnel* must necessarily be less accustomed to the peculiarities of their boilers than they will be later, when the ship has been in service for several years. On the *Sachsen*, the partial interior cleaning takes place on an average every ten days, and a boiler keeps four men busy for about twelve hours.

In a complete interior cleaning, all the conical caps are screwed off the tube ends, all the covers and internal tubes are withdrawn, the covers and junction faces in the header are carefully cleaned, and, if necessary, ground with emery paper. The boiler tubes are not removed, but scraped inside with spiral wire brushes and then scrubbed with cotton soaked in soda. Mud deposits near the tube ends can be pushed out or removed by scouring. The internal tubes are annealed at dark-red heat, and then brushed inside and rubbed dry outside. The receivers and headers are scraped and washed.

This thorough internal cleaning of all the eight boilers, which is applied once or twice every year, takes on the *Sachsen*, with eight non-commissioned officers and forty trained stokers, about 77 hours.

The accelerated removal of the covers of the headers, of which the recent types of boilers admit, will quicken the work of these partial and thorough cleanings. In the old types of Dürr boilers, the covers could be taken out only through the openings provided in front of the lateral and, partly also, in front of the lower tubes, and they had to be shifted, with difficulty, within the water chamber from hole to hole. On the *Prinz Heinrich* such holes are placed also in front of the upper rows of tubes, and on the large new cruiser *B* further in front of two vertical rows of tubes. These large openings in the front wall of the water chambers

are shown dotted on the diagrams. The covers of ordinary size can pass through them, whilst the larger covers can be removed through some oval holes.

In this way the removal of the covers has been considerably facilitated. To take out one cover would, on the *Sachsen*, in the worst case, necessitate the removal of eighteen other covers. On the cruiser *B*, the operation may, under the most unfavorable conditions, have to be extended to nine other covers.

NECESSITY AND EXECUTION OF REPAIRS.

The receivers and the welded headers will, it may be expected, hardly develop leaks calling for repairs in the course of a good many years. The influence of the bilge water, which often damages other types of boilers, does not demand attention, as the Durr boilers stand high. Erosions in the interior of the water chambers and in the tubes will, on the other hand, not be altogether avoidable; that applies to other boilers as well. The brisk circulation of the water, and the entire absence of copper, materially lessen trouble from this source, however. The receivers and water chambers are everywhere accessible, and with careful attendance and timely cleaning any incipient pitting can be stopped by filling the corroded portions with glycerine cement. The spreading of pittings in the tubes cannot be prevented in this way; but careful examination of the boilers will reveal their presence, and their extent and depth can be determined by the aid of measuring instruments and test holes with a fair degree of reliability. Punctures proceeding from outside are not to be feared in galvanized tubes, so far as experience goes.

Particular attention has, however, to be paid to the badly accessible portion of the headers below the lowest row of tubes. The water does not circulate there, the material is weakened by the welding operations, and these portions are difficult to drain perfectly when the boilers are emptied.

The superheater tubes are rather liable to internal pitting, as access to them, for the purpose of examination and preservation, cannot be gained without considerable trouble. With the horizontal disposition of the superheater tubes of the early Dürr

boilers, and their defective arrangements for draining, some water may remain in the tubes when the boilers are opened up and are to be kept dry. When kept under water, on the other side, it is difficult to fill the tubes completely with water, and to expel all air, because the water can only enter into the superheater tubes through a slot situated at the level of the highest portion of the receiver. In order to facilitate both the emptying and the refilling of the superheater tubes, and to provide improved means of escape for the air, special devices have been projected for the new boilers; and it is also intended, contrary to the original plan, to give these tubes on the cruiser *B* an inclination upwards.

As regards the covers and the tube cones, which proved somewhat liable to leakage in the experimental boiler and on the *Baden*, no trouble has been experienced in the later boilers. It need hence not be feared that the conical faces of the water chambers will be destroyed by a continued incurable leakage in such a junction. When the joint has become very rough, the faces can be reshaped with tools which are available on board. Nor is any wear and failure likely to occur at the junction between the tubes and the diaphragm of the water chamber, particularly because the tubes are not taken out except on rare occasions. Tube cones which have turned out too small can be expanded on board between rolls in a ring.

The internal tubes are made of folded strips. At the commencement they had to be renewed very frequently. They were then strengthened, the front portion receiving a wall thickness of 1.5 millimeters, the rear of 0.75 millimeter; and as there is now little necessity for opening the boilers, it may be presumed that the new styles of tubes will last several years. A few punctures in the internal tubes would not render them useless.

The covers called for frequent renewals in the early years. In many cases the covers had been over-tightened, so that the threaded pins broke during fixing or removal, or the cones had been forced so deep into the openings that the covers would not fit firmly after having been replaced a few times, and that the safety collars pressed against the header walls. Hundreds of

covers had to be condemned as waste for these reasons. The men have meanwhile learned to tighten the nuts of the covers gently, after previously rubbing them with cock grease, with the aid of a short wrench, and to tap skewed covers from which steam escapes, all round with the wrench so as to get them into proper position. The number of cover replacements has very considerably decreased accordingly. The covers of the most recent boilers are made by the Dürr Company of a very tough iron, with a strength of from 36 to 42 kilogrammes per square millimeter, and an elongation of 25 per cent. Another improvement is that the conical faces have been lengthened; the covers can now penetrate further into the holes before they strike their seats.

When a pin breaks a spare pin can be screwed into the bored and threaded cover and riveted in it. Cones which pass too far into the header wall can be expanded on board.

On each opening up of a boiler, a certain number of the packing rings and hooks which hold the internal tubes (see Fig. 3) are spoiled. These parts can be renewed from the spare stock, and also be made on board, should the necessity arise.

Whether or not the conical caps closing the tube ends will call for frequent renewals remains to be seen. Nor is it known how long the boiler tubes will last. A tube can, anyhow, be replaced on board without difficulty.

The boiler casing, the rougher fittings and the rear walls are, on board the *Prinz Heinrich*, sufficiently strong; there will be little need for their repair.

These various considerations point to the conclusion that the Dürr boilers will presumably run for many a year before serious repairs will prove necessary, and that it will be easy to effect almost all the repairs which we may apprehend on board.

SUMMARY OF THE ADVANTAGES AND DISADVANTAGES OF THE DÜRR BOILERS.

In conclusion, the advantages and disadvantages offered by the Dürr boilers, and touched upon in this article, may briefly be tabulated.

As disadvantages must be considered:

1. The sensitiveness of the boilers to sea water, and the resulting necessity of exercising great care in the attendance of the spare feed pumps and in the supervision of the condensers.

2. The necessity of placing the boilers in the fore-and-aft line.

3. The comparatively onerous operations which the partial interior cleaning and the change of water involve.

4. The multitude of parts, the consequent great variety of the many small repairs and cleaning operations, and the large number of spare parts and special tools required.

5. The necessity of a skillful and specially trained *personnel* to see to the cleaning.

As advantages are to be regarded:

1. That the boilers are insensitive to the rapid rising of steam, quick cooling, and strongly forced drafts.

2. The accessibility of all portions for examination, cleaning, and repairing.

3. The possibility of effecting all repairs with means available on board.

4. The possibility to feed, in cases of emergency with well water.

5. The good circulation of the water in all parts and under all working conditions.

6. The high evaporative capacity of the boilers, which permits of burning 180 kilogrammes and more of coal per square meter of grate area (37 pounds per square foot).

7. The presumably long life of the boilers.

There are thus, on the one side, weighty constructive advantages, and, on the other, drawbacks which concern almost exclusively the attendance and cleaning of the boilers, and will mainly be felt by the *personnel* on board.

The increased share of duties which falls upon the stokers is, indeed, a serious disadvantage for the Navy. It is to be hoped, however, that greater familiarity with the properties of the Dürr boilers will simplify the working and the cleaning, and that the common efforts of the Imperial Navy Department, the Imperial Wharves, the commanders, and the Dürr Company, will result in further improvements of the Dürr boilers.

ORGANIZATION OF THE ENGINEER DIVISION ON BOARD A MAN-OF-WAR.

By Lieutenant C. W. Dyson, U. S. N.

Upon reporting for duty as senior engineer on board a vessel going into commission, and especially if it is the vessel's first commission, one of the most important problems an officer finds staring him in the face is that of forming the force detailed to the engineer division into such an organization as will produce that smooth and clock-work action which is required in a military body. Everyone must have a place in all work and drill of the division, and everyone must know his place.

To make each man's station bill as simple as possible, so that he may be able to commit it to memory without any great effort, his duties at all drills and in the work of the department should be so laid out as to practically confine him to one particular portion of the department.

In order to make as clear as possible my ideas as to the proper organization of an engineer division I will assume an engineer division having the following strength:

1 chief engineer.

Assistants: 4 warrant machinists.

Enlisted force.

1 chief yeoman.	1 coppersmith.
4 chief machinists.	6 water tenders.
4 machinists, first class.	12 oilers.
8 machinists, second class.	17 firemen, first class.
2 boilermakers.	13 firemen, second class.
1 blacksmith.	47 coal passers.

Total strength of division, 116 men and 5 officers.

The first step in organization will be to divide the department into four parts, as nearly equal in the amount of work carried by each part as possible. The senior warrant machinist will be placed in charge of the main engine rooms, main engines, shaft alleys, engine-room auxiliaries, and double bottoms under engine rooms and shaft alleys.

The second warrant machinist will be assigned to all boilers, fire rooms, bunkers, double bottoms, feed pumps and ash hoists on the starboard side, and the third warrant machinist to those on the port side of the vessel.

The junior warrant machinist will have charge of all machinery outside of the engine room and fire-room bulkheads and hatches, all steam and exhaust piping, outside the same limits, leading to this machinery, and all steam-launch machinery.

The mechanics of the department must now be assigned to these different sections of the department in such proportions as will most probably give each man about an even share of the work. The force given is about what is required for one of our battleships. As there are two main engines, we shall assign to each engine room one chief machinist, with two machinists, second class, for work on the main engines, and one machinist, first class, for work on the engine-room auxiliaries. This detail will give a total of two chief machinists, two machinists, first class, and four machinists, second class, for repair section No. 1.

For repair sections Nos. 2 and 3 we shall allow one chief machinist, two machinists, first class, two machinists, second class, and two boilermakers.

For repair section No. 4 we assign the remaining machinists, viz: one chief machinist and two machinists, second class.

The blacksmith is not assigned to any section, but is available for duty wherever his services are required, and the coppersmith is similarly situated.

Having now provided for the repair work, the general cleanliness and condition of the department must be looked after.

For the engine rooms with the shaft alleys, hatches and machinery therein we have twelve oilers, of which three will be required for each main engine, one for the main air and circulating

pumps in each engine room, one for the feed, fire and bilge, and water service on each side, and the remaining two for the evaporators, distillers and their pumps on each side. In addition to these men, three firemen, first class, and three coal passers will be assigned to each engine room to clean the bulkheads, hatch and shaft alleys.

The double bottoms under this portion of the department will be cleaned by the men having the above cleaning stations, their work in the double bottoms being done under the supervision of the machinists, second class, of each engine room, who will report it to the warrant machinist in charge of that repair section when ready for inspection.

The cleaning stations, as divided above, will be apportioned among the machinists of all grades assigned to engine-room work, and they will be held responsible by the officer of the watch if the work is not properly done.

Passing now to the fire rooms: Let us suppose we have eight fire rooms. In charge of each pair of fire rooms, fore and aft, we shall place a water tender, who also has charge of the double bottoms underneath these two fire rooms and their boilers. His jurisdiction will extend to the berth-deck gratings. To each fire room will be assigned one fireman, first class, one fireman, second class, and two coal passers, each fire room constituting a station and the water tender in charge being held responsible for its cleanliness. These same men will clean the double bottoms under their fire room and half way under the boilers to the adjacent fire rooms, the water tender inspecting their work and reporting it when ready for inspection to the warrant machinist in charge of that repair section. The water tender with his force will also have charge of the boilers in his particular compartments, and all work necessary for their care and preservation will be attended to by him and his special force.

The bilges in the department will be cleaned by the men having their cleaning stations directly above them, and their condition will be looked after by the petty officers having charge of the compartments in which they are located.

The fire-room hatches above the berth-deck gratings will be

put in charge of the two remaining water tenders, and there will be assigned to each hatch two coal passers or two firemen, second class, to keep them in order, their cleaning stations extending from the berth-deck gratings to the outside upper gratings.

The ice machines with their compartments will be cleaned by the men detailed to stand watch on these machines, four men—one firemen, first class, and three coal passers—being detailed for this watch duty.

For the cleaning of the ventilating blowers and any other steam machinery which may be located on the orlop deck one coal passer should be detailed, and he should not be called upon to perform any other duty unless it becomes absolutely necessary, the work of this man being arduous and confining.

To the steam launches, of which there are at least two, will be assigned two regular crews, one for each, consisting of one fireman, first class, and one coal passer, and one relief crew made up of the same ratings. The two regular crews will be held responsible for the cleanliness of the boat so far as the machinery and bilges under and bulkheads around the machinery are concerned, and will not perform any watch duty at sea unless through shortness of complement it becomes necessary to call upon them.

The store rooms will be placed in charge of the chief yeoman, who also will have charge of the department's books and log room. He will be assisted by a chief store-room keeper, who will be a fireman, second class, and an assistant store-room keeper, who will be a coal passer. He will be held responsible for the proper care of both stores and store rooms, and should submit a daily account of the issue of stores to the senior engineer officer for his inspection.

Two coal passers will be detailed to the care of the wash rooms and machine shops and will not be available for other duty except in case of urgent need.

The twelve remaining coal passers will act as mess cooks and helpers where separate messes are maintained. Where the vessel has a general mess only six men would be needed for this duty. This number, of course, can only be approximated, as the

number of mess cooks required would depend upon the number of messes into which the force was divided by the executive authorities of the ship.

In coaling ship and also in the care of the bunkers, the firemen, second class, and the coal passers stationed in the fire rooms adjacent to these bunkers will be used, being reinforced by those having stations outside the strict limits of the department. The water tenders having charge of the adjacent fire rooms will superintend repair work in the bunkers, such as scaling and painting, while all the water tenders will be used to superintend the stowing of coal. When it is required to be done by the engineer division, the coal will be weighed and tallied by oilers especially detailed for that purpose. Oilers will also act as reliefs in superintending the stowage of the bunkers.

All the repair and cleaning stations being provided for, the stations for general quarters, fire and collision drills must be allotted. It has always been the custom of the writer to base the duties for all these drills upon the duties for general quarters, only noting in each man's billet the additional duties to be performed at either of the other drills, and always requiring him to return to his general-quarters station after these additional duties have been performed.

It has also been the aim to have the men stationed as nearly as possible at these drills in the same compartments and with the same machinery to which they are assigned in the general work of the department, the skilled men of the engine rooms who are not required there at these drills being stationed at the various machines outside the department which are in operation during the drills, and also at the forced-draft blowers to see that they are properly oiled and properly operated, these machines being divided into groups with a machinist in general charge of each group. The firemen should not be called upon to fire more than about forty square feet of grate at these drills if good results from working under forced draft are to be expected. All the firemen, first class and second class, should be used in the department, the firemen, first class, and as many firemen, second class, as may be needed to work the fires, and the remaining

firemen, second class, and as many coal passers as may be necessary, to pass coal, each fireman on the fires having his own man to provide him with coal. The remaining coal passers will be assigned to the powder division for these drills only.

As the regulations require the men to stand watch in not more than three watches, and as three-fourths of the force are usually sufficient for these watches at economical cruising speeds, using three-fourths the boilers, the engineer's force may be divided into four watch sections, the extra section being utilized as the working section, and used for all repair and cleaning work that may occur while steaming. Each section will act as the working section in turn. There will be a column on the watch, quarter and station bill showing each man where, when his section is acting as working section, he will report when all boilers are in use, for assignment to steaming duty; and there will also be another column showing where he will report for assignment when the division is divided into two sections for full-power steaming, the section on watch when full power is called for, always remaining on watch until their watch would regularly end and the additional men coming below and reporting for duty.

The following form will show the combined watch, quarter and station bill arranged according to the foregoing ideas:

In filling in the columns of the watch, quarter and station bill, column *a* should be inked in permanently, as after a man is once assigned to a section he is not supposed to be shifted out of it until a change in his rating occurs, when he is shifted to the vacant number of his new rate. Column *b* should be in pencil, as, on account of changes of rating, discharges or casualties, the personnel of the force is being continually changed. Column *c*, being permanent, should be in ink, as should *e*. Column *d*, however, must be in pencil, as the pay number goes with the individual. Column *f* should be in pencil, as very often, when a man changes his ship number for any cause, it is desirable to carry his cleaning station with him on account of the satisfaction he has given in that particular station. The remainder of the columns are permanent, and the stations should be entered in ink.

In order to reduce the size of the bill, which would be very

CHIEF ENGINEER....., U. S. N.

FIRST ASSISTANT ENGINEER....., U. S. N.

SECOND ASSISTANT ENGINEER....., U. S. N.

FIRST SECTION.

Ship number.	Name.	Rate.	Pay number.	Boat at abandon ship.	Cleaning and repair.	Double bottom.	Gen. and fire quarters and collision drill.	Steaming station.	Division for all boilers.	Division for full power.	Ship number.	Name.
a	*b*	*c*	*d*	*e*	*f*	*g*	*h*	*i*	*k*	*l*		

STEAMING STATIONS.

No. of Station.	Duty.	No. of Station.	Duty.
1		13	
2		14	
3		15	
4		16	
5		17	
6		18	
7		19	
8		20	
9		21	
10		22	
11		23	
12		24	

WATCH, QUARTER AND STATION BILL.

ENGINEER DIVISION.

U. S. S.....

SECOND SECTION.

...me.	Rate.	Pay number.	Boat at abandon ship.	Cleaning and repair.	Double bottom.	Gen. and fire quarters and collision drill.	Steaming station.	Division for all boilers.	Division for full power.

T

Ship number.	Name.	Rate.

CLEANING AND REPAIR STATIONS.

No. of Station.	Duty.	No. of Station.	Duty.
1		13	
2		14	
3		15	
4		16	
5		17	
6		18	
7		19	
8		20	
9		21	
10		22	
11		23	
12		24	

H. QUARTER AND STATION BILL.

ENGINEER DIVISION.

T. S. S.....

THIRD ASSISTANT.....

FOURTH ASSISTANT.....

CHIEF YEOMAN.....

THIRD SECTION.

and collision drill.	Steaming station.	Division for all boilers.	Division for full power.	Ship number.	Name.	Rate.	Pay number.	Boat at abandon ship.	Cleaning and repair.	Double bottom.	Gen. and fire quarters and collision drill.	Steaming station.	Division for all boilers.	Division for full power.	Ship number.

EANING AND REPAIR STATIONS.

	No. of Station.	Duty.
	13	
	14	
	15	
	16	
	17	
	18	
	19	
	20	
	21	
	22	
	23	
	24	

STATIONS FOR GENERAL

No. of Station.	Duty.
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	

....., U. S. N.

....., U. S. N.

....., U. S. N., Aid to Chief Engineer.

FOURTH SECTION.

Name.	Rate.	Pay number.	Boat at abandon ship.	Cleaning and repair.	Double bottom.	Gen. and fire quarters and collision drill.	Steaming station.	Division for all boilers.	Division for full power.

ERAL AND FIRE QUARTERS AND COLLISION DIVISION

y.	No. of Station.	Duty.
	13	
	14	
	15	
	16	
	17	
	18	
	19	
	20	
	21	
	22	
	23	
	24	

large with the complement of one of our battleships, the stations for cleaning and repair, steaming, and general and fire quarters and collision drill are given numbers, and these numbers with the corresponding duties are set down in tables beneath the columns of the detail bill. The numbers of the stations are entered in the columns of the bill in place of writing out the particular duties of each man opposite his name.

Where, outside the fire rooms, the stations on the two sides of the ship are identical in everything but location they have the same number, the particular station intended being shown by adding starb. or port to the station number. In the fire rooms, where the stations are identical, the same number is given to identical stations, the location being shown by the addition of F. R. No.

In dividing the division into its four sections the sections should be made of as nearly equal strength as possible, both as to the physique, professional ability and rating, the duties of water tenders in one section being performed by the blacksmith and coppersmith. Then in assigning men in column *k* the men of any one section are divided as equally as possible among the other three sections, so that the equality of steaming strength of the sections will be maintained when working on a three-section basis. This column also indicates the proper men to call upon when any section becomes short from any cause; all men of the section forming the working section at the time, who have a number assigned them in column *k*, the same as the number of the section requiring reinforcement, will be called in, rate for rate, until the existing vacancies in the steaming section have been filled.

In making the details in column *l*, the four small steaming sections should be combined to form two large steaming sections, in such a manner as will most likely insure that no section which has just completed a watch will be called down immediately after having been relieved. In order to do this we throw together the first and third sections, and the second and fourth. Upon being called below for a full-power run, the engine-room men proceed at once to their ordinary stations in the engine

rooms and divide the duty with the men already on watch. In the fire rooms the men will report to the water tenders for assignment.

This bill as here proposed was adopted on board the U. S. S. *San Francisco* during the war with Spain, and in a few days, as soon as it had been thoroughly explained to the men and was thoroughly understood by them, worked very smoothly and satisfactorily.

Laying out the work of the department.—There is on board ship a great amount of routine work which we can assign to different days, and so make out a weekly, monthly and quarterly routine, and this routine work for each day will always be carried out unless more important work should interfere with it. In laying out the work for the day, the senior assistant of the department should take the orders for work given by the senior engineer officer the evening before, and in the morning make out a list of men available for work on that day and divide them up among the different items of work as the importance of the items may require, putting the surplus to work according to the regular routine. During the morning watch the only work done should be such as washing clothes, hoisting ashes and cleaning stations and bilges, except in an emergency, when repair work must be carried on.

During working hours, after breakfast, when there is much work in all parts of the department, the assistants should remain on board, each one looking after the work in progress in the section of the department under his particular charge. At the end of the working hours those assistants not having the day's duty may be given permission to apply for leave.

One great necessity for properly carrying on the work and keeping a correct record of the work of the department is a proper form. This could be furnished in book form of such size and arrangement as would suffice for a yearly record in the one book. The general form which is proposed is given on opposite page.

The books would be formed of sections of twelve pages, every twelfth page being as shown, while the other eleven would be as shown from *a* to *b*. Page 12, while similar to the others in all

WORK BOOK FORM.

Name and rate.										
Day.	MONTH ..... 1901.									
1										
2										
3										
4										
5										
6										
7										
8										
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respects, has in addition an index of names for ten men. The largest force carried by any of our vessels in war or in peace would require a book of about 192 pages, consisting of 16 of these sections of 12 pages. Each page embraces the duty and work details of each of the ten men on the index or December page for one complete month, and the twelve pages will give a complete history of the duty and work performed by each of these men for one year. By keeping a record of this kind, which will be easier to keep than the regular steam log, we will also have the working history, so far as repairs necessary are concerned of every machine on the vessel, and have it in a much more get-at-able form than in the steam log. It will also act as a record in black and white of the quality of the work preformed by the different mechanics of the department.

This book would be used by the senior assistant in detailing the men of the department for the day's work. Under each man's name he would enter the man's duty for that particular month and day, whether *on watch*, in *steam launch*, *cook*, *sick*, *absent*, in *confinement*, or the special work he was to perform if available for general work, and when the men reported for work at "turn-to" after breakfast each man's duty for the day would be read off to him. As carried on at present, we have the record for the day only of what each man is doing during that day. When the working hours are over the old detail list is destroyed and a new one is made out. The result of the present system is that after an item of work performed is two or three weeks old we must depend upon our memories entirely as to the man or men who had been employed upon this particular work; and sometimes, after the quality of the work develops, we find that the job has been badly scamped while we have no absolute record of the individuals whom we should hold responsible for such a performance of duty.

One of the most disagreeable and also one of the most important duties which falls to the lot of an engineer officer on board ship is that of superintending the stowage of coal in the bunkers. On board ships having very large bunkers, as in the battleships, this is quite an easy matter, as the bunkers practically stow

themselves until but a small percentage short of their total capacity; but on the smaller vessels and on those having a large number of small bunkers we have an entirely different case to handle. In a great many of these small bunkers the chute enters at one end or at the side, and it is necessary to begin trimming the coal almost from the time the first pound is put in the bunker. If the reports of the coal passers stowing and of the petty officers in immediate charge of each set of bunkers could be depended upon, the lot of the engineer officer would be a very pleasant one; but, unfortunately, this is not the case, and the officer can only be assured of the proper stowing of the bunkers by visiting them occasionally and checking up the reports of his men by personal inspection of the actual condition of affairs. While the greater percentage of the men of the engineer divisions of our vessels are trustworthy and hard working, there are among them a set of worthless good-for-nothings, whose only desire is to get through every duty with the least possible expenditure of physical energy, and if proper care is not taken it is this class of men that puts the senior engineer officer in that most embarrassing of situations—that of reporting to the commanding officer the discovery of a large deficiency in his coal. When stowing small bunkers the coal passers will allow the coal to bank up under the chute until further entrance to the bunker is impossible, and will then report the bunker full, when in reality it may lack at least twenty per cent. of being full. When this occurs with a large number of bunkers the total deficiency amounts to quite a large percentage of the coal capacity of the vessel, and serious trouble may be caused by it. The only way to prevent this is to positively require that the petty officers in direct charge of the bunkers shall report each bunker to the officer in general charge of the stowing when it reaches the point of being ready for the last one or two tons, and that this officer shall then satisfy himself as to the stowage by making a personal inspection of the bunker. This duty is dirty and disagreeable, but it is the only way in which anything near a proper stowage can be obtained.

To still further guard the coal account it must be insisted

upon at sea and in port that every pound of coal taken out of the bunkers must be measured out in the coal buckets. The coal passers object very seriously to this, as it adds much to their work in getting out the coal, and the firemen also object, particularly when they are in a hurry to get the coal out on the floor plates for immediate use. The favorite fire-room practice in measuring coal is to have each fireman keep account of the number of shovelfuls of coal he has put on the fires during each hour of his watch. This is a most excellent way of keeping the coal account when it is desired to make a good showing as to coal expenditure per day, but unfortunately it always necessitates periodical entries at the head of the log sheet of the expenditure of a large amount of coal to correct deficiencies discovered by inspection of the bunkers. This trouble is very liable to occur when the commanding officer of a vessel calls for a certain speed for a fixed coal expenditure per day. No matter what the quality of the coal, the amount of coal expended handed in hourly to the machinist of the watch will very seldom, if ever, exceed the number of buckets per hour which the senior engineer officer has fixed as the limit to be used. This stealing of coal will also occur when the order is passed to make all the revolutions possible on a fixed coal expenditure per day, and particularly when the men of the different steaming sections are filled with the desire for each man's particular section to surpass the other sections in results obtained as shown by the speed and revolution columns of the steam and deck logs. It is very desirable to keep this spirit of emulation alive, for there are times when it is needed, as in a forced run, when no limit is set upon the amount of coal to be used or speed to be obtained. It may be argued that the theft of coal may be avoided if the engineer officer of the watch stands his watch in the fire rooms. The fire rooms are the proper place for him to spend his watch, for if the repairs and adjustments in the engine rooms have been properly attended to while the vessel was in port, and if the engine-room force is competent, and it is, except in very rare cases, good results as to speed and economy can only be obtained by close attention to the work of the fire-room force. However,

even if the officer on duty does spend the greater part of his watch in the fire rooms, there are several of them, and while he is looking after the measuring of the coal in one it will be coming out of the bunkers on the blades of the shovels in the others, all the men keeping their eyes open to notice his approach and to get the warning word passed in time. In the opinion of the writer, the only way in which the coal tally handed in to the desk can be made reliable is for the commanding officer to set the number of revolutions desired and allow the engineer officers to look after the coal. The coal passers are not so fond of work that they will get out any more coal than is required by the fires for the revolutions asked for, and they are pretty good judges of the ability of the fireman for whom they are getting out the coal. The firemen themselves do not care to handle any more coal than is necessary, and they also know that they can kill their fires by overfeeding them, and so throw more work on their own shoulders in getting them in proper condition again.

The watch duties of the division in port should be so arranged that every man in the force, with the exception of the chief petty officers, the boilermakers, blacksmiths, coppersmiths and cooks, will be given their proper share. In order to insure this the details should be made weekly, and a book kept in which these details are entered, so that in case of any man urging that he is being assigned to more than his proper share of watch duty his claim can easily and quickly be settled by referring back to these weekly detail records.

Finally, in giving liberty to the men of the engineer force, the division should be divided into as many liberty sections, with equal numbers of men in each section, as the deck force of the vessel, and no man should be allowed to have his name entered on the engineer's liberty list on other than his proper liberty section day unless he reports to the senior engineer officer that he has special permission from the executive officer to have his name so entered, and, before obtaining this special permission, ascertaining from the senior engineer officer whether there is any objection to his going on liberty that day. The liberty list will be prepared by the engineer officer having the day's duty,

and he should notify the senior engineer officer if the absence of any man whose name is on the list will delay the work of the department. This list as submitted by the engineer officer having the day's duty, and, after being corrected and recommended by the senior engineer officer, will be sent to the executive officer's office for his inspection and for entry in the ship's liberty book.

It is hoped that the publication of the views and ideas contained in this article may bring out the views on the same points, and on any others relating to the subject which may have been omitted, of other officers of the service, that the organizations of the engineer divisions of our ships may be made more uniform, and also so that among the printed forms furnished the ships by the Navy Department may be included a form of watch, quarter and station bill, satisfactory to the great majority of enginer officers.

Discussion.

Lieutenant Commander Parks, U. S. Navy.—Where there are four warrant machinists I prefer to divide the department for repair and cleaning in a slightly different way from the one advocated by Lieutenant Dyson.

The comfort of the Chief Engineer and his freedom from little worries is so dependent upon the good condition of the auxiliary machinery outside the engineer's department proper, and upon the efficiency of the water-making plant and the steam launches, that I am selfish enough to give these machines the benefit of the best talent in the force.

I would put, then, one warrant machinist in charge of engine rooms, shaft alleys, engine-room auxiliaries and double-bottom compartments underneath engine rooms and shaft alleys.

One warrant machinist in charge of all steam auxiliary machinery outside the limits of the engineer's department proper, and the evaporating and distilling plant wherever located.

One warrant machinist in charge of all boilers and boiler-room auxiliaries, with double-bottom compartments underneath the fire rooms.

One warrant machinist in charge of all steam, exhaust and water pipes above the protective deck and outside the bulkheads of engine and fire rooms; all hydraulic engines and the steam-heating apparatus; also all bunkers, including their doors and scuttles.

I prefer to subdivide these four repair stations into smaller cleaning stations, two or three to each, except in the fire rooms, where each boiler-room compartment forms a cleaning station. Each cleaning station has a chief, a petty officer, and as many men as experience shows to be necessary. The men of the repair station furnish the labor for the cleaning stations into which the repair station is divided, and the chiefs of these cleaning stations are responsible to the warrant officer in charge of the repair station.

I agree with Lieutenant Dyson that stations for all drills should, as far as possible, bring the men to their cleaning and repair stations.

When there are two or more steam launches I have had success by putting the launch machinery in charge of a chief machinist, who did nothing else but look after these boats and their firemen crews. With three launches one chief machinist had about all he could do at first; later, when, by systematic work on repairs and careful selection of crews, he could take some measure of ease, he was not taken off for other work.

A most important crew to select is the evaporator crew. I prefer to pick out four men for this duty, giving them four watches, and let them arrange their tours of duty among themselves. This plan has worked well, both on the evaporators and on the ice machine. It was fully understood that going on liberty was not to interfere with the running of the evaporators or ice machine.

I cannot agree with Lieutenant Dyson as to the necessity for the four-section organization. It would probably not be applicable to all ships. The present three-section arrangement is well understood, and is familiar to newly-shipped firemen and coal passers, who generally come from the merchant service. When the number of men required for steaming is less than the num-

bers in the sections, men can be dropped out of each section to form a working party. This working party can then be worked by watches, or as a whole.

The station bill should show the stations of officers and men for preparing to coal ship, and for coaling ship. To avoid burdening the men's memories with too many individual stations, I believe it is best to write on the station bill where the sections will be stationed, and their duties as sections, for preparing to coal and for coaling. The responsible officer, or petty officer, of each section could then distribute his men to the best advantage for the work in hand.

Two very important duties of the Chief Engineer and his assistants are the details for auxiliary watch, changed every week, and the daily liberty list. Just here it may be well to emphasize the fact that the conditions at work and life for the men of the engineer's force are different from the conditions under which the deck force live and work. This difference of conditions prevents absolute uniformity with the deck arrangements for duty and liberty. I think it would be well if this difference of conditions were recognized as requiring a different system of messing—different food, and probably different hours for meals.

The deckhand may go on liberty whenever the day for his section comes around without inconveniencing anyone; but with the fireman, that day may find him on auxiliary watch, and endless confusion and trouble arise if he has to have a relief for the time of liberty. I have always made it the rule that no man could go on liberty the week he was on auxiliary watch. Arrangement can generally be made with the executive officer so that the men of the engineer's force get just as many days of liberty as their conduct class entitles them to, although this liberty going may not always be as continuous as that of their shipmates of the deck force.

The suggestions for keeping account of repair work are excellent.

Lieutenant Commander Gow, U. S. Navy.—The subject considered by Mr. Dyson is one that has long needed discussion

by the officers of the Service, and some uniformity established, and it seems to me that his scheme is very well worked out. The system in use on many of our ships, by which each man has a different station for the various drills, according as he is either the first or second relief, in my experience does not work well in practice. For all drills, as far as possible, a man should always go to the same station. A man should not be required at one time to go to the fire room, and at another to the powder division, as such arrangement only tends to confusion to both divisions. Coal passers should be permanently detailed to the powder division; and when the call sounds, if on watch, should first be relieved by some of the firemen.

To divide the force into four watches, and only use three when steaming, does not strike me as favorably as the arrangement instituted on this ship (*Massachusetts*), by Mr. Dyson, when Chief Engineer. Here each man belongs to a given fire room, both for cleaning and watch duty. If in case his fire room is not in use, owing to only two or three of the boilers being in use, then he does not stand watch and is available for repair or other work.

The available list also permits filling out vacancies that may exist in fire rooms that are in use.

Such bill should be printed in large type, with ample blank space, to fit it to different ships, and with numerous extra numbers, in case they may be needed.

Lieutenant A. Moritz, U. S. Navy.—I agree with Lieutenant Dyson in advocating four sections for the engineer division, but would extend the idea. Article 657, paragraph 3, U. S. Navy Regulations, states, that "for ordinary steaming the force shall be divided into three sections." This should be modified to read, "shall be divided into *not less than* three sections *except in cases of emergency*," and thus permit the senior engineer and the commanding officer more discretion in the organization of the engineer division.

Men should not be placed in *less* than three watches except in cases of absolute necessity, when full power is required, and then only for the shortest time.

For cruising in the tropics "three watches" is too exhausting, especially as the men are called on for many routine things necessary on a man-of-war, such as "air bedding," "up all bags," "abandon ship," "general quarters," "fire quarters," and to attend the usual morning and evening quarters, all of which encroaches on the men's brief intervals of rest.

The four-section arrangement works very well with the routine of the ship; it gives the men a better chance to keep themselves clean and in good physical condition; it affords good opportunities for drills belonging to the ship outside the engineer department.

For full-power runs, general quarters, or fire drills, the division is divided into two parts, as suggested in Lieutenant Dyson's paper. On such occasions on the *Brooklyn* and on the *Newark*, if the first section happened to be on watch the third went below. The firemen, second class, and the coal passers, except messengers and store-room keepers, of the second section went to the powder division aft, and those of the fourth section to the powder division forward, or *vice versa*; second and fourth sections below and the first and third sections to the powder division aft and forward. In this way the powder division always got the *same* men, either of the third or fourth sections, for forward, and the *same* men, either of the first or second sections, for aft, without confusion and with little or no opportunity for a man to shirk duty on petty excuses.

In port the same arrangement works well. A few of each section are required for the routine port watches, care being taken to select the men employed at the ice machine, distilling apparatus, steam launches, store rooms, messengers, etc., from all sections in equal numbers as far as possible.

One section must remain in the uniform of the day and be ready for any drill, call of "all hands," or for any light, clean engineering duty required outside of the engine and fire rooms. This section is also entitled to liberty on liberty days.

In regard to coaling, a great deal can be said. At present there is a division of responsibility on board ship, not conducive

to the best interests of the ship. The equipment department receives the coal and transfers it to the engineer department.

The U. S. Navy Regulations now in force should be modified to make it obligatory for the equipment officer to receipt for the amount as weighed or measured into the bunkers, and which the senior engineer is willing to sign for, as the correct amount. Some allowance must be made for a loss in handling. This will vary according to the method and circumstances attending the coaling of a ship. One per cent. is, to the best of my knowledge, a commercial allowance for each handling. This allowance for coaling a war vessel, except when done in very smooth water, or when done with unusually good facilities, is far too low. After very careful observations on many occasions, I have noticed the loss to be from 5 to 10 per cent. When coaling with 50-pound baskets, one little lump of $2\frac{1}{2}$ pounds falling overboard from each basket would entail a loss of 5 per cent., equivalent to 25 tons in 500 tons. Although such losses must be recognized, they can be and should be minimized by careful work. In my opinion, the best way to receive coal on board is by measurement, 45 cubic feet to the ton, or by the actual weight of car loads. If the contractor objects to allowing 45 cubic feet to the ton and it is taken at less, the commanding officer should give an order, with explanatory note, to the senior engineer to expend the difference immediately on his books.

A good, reliable check as to the actual amount of coal received on board ship is to take the draught forward and aft before and after receiving the coal and multiply the average difference in inches by the number of tons required to immerse the ship one inch. Our ships generally possess the necessary data.

In regard to the "stealing of coal" in the fire rooms, I have found it impractical to work on coal allowance and revolutions at the same time without accusations of this nature being made by one section against another. Besides, there is some danger of water tenders allowing the water to run low to make a good show, or there is more or less neglect in the matter of cleaning fires or tubes.

The commanding officer should only give the speed. The

engineer will know how much coal is necessary to make it and the other economical points.

In coaling ship, one or two junior engineer officers should be placed in charge, with power to act to get the best result as to stow or trim of the bunkers in the quickest time. Of course they must work under instructions of the senior engineer, who in turn is responsible to the commanding officer. I have known officers-of-the-deck and executive officers to interfere, perhaps unintentionally, and disturb or break up well thought-out plans of a junior officer.

Commander Geo. H. Kearney, U. S. Navy.—The subject of the organization of the engineer's force on board ship is an important one, on which it would be well, if possible, to establish an uniform rule, but as vessels differ so materially in their internal arrangements it is very doubtful if any one general form of station bill can be made to suit all cases.

The general principle should be followed, that each man is stationed for general, fire and collision quarters, cleaning and overhauling in the one compartment, but in steaming, as usually done, with less than full power, the stations must change in the fire rooms.

The force should be stationed so that there is a machinist or water tender in charge of each engine or boiler compartment, and then the men assigned to each compartment, having regard to the kind and amount of work in each space, including the bilges, double bottoms, bunkers or other spaces opening into the compartments, as well as the compartments directly above the engine or fire rooms that are cared for by the engineer's force, and that machinist or water tender should be held responsible for the condition of the parts of the vessel so assigned.

The station bill should show what each man is to do in those compartments at each drill, which is generally the same thing in the above drills.

As the machinists, water tenders, oilers and firemen are of much more value in the engine and fire rooms than when doing the ordinary manual labor usually assigned them when detailed

for the powder division, such detail should be made from the list of coal passers, and so arranged that the coal passers from the divisions off watch go to the powder division while those of the watch on duty below remain at their work.

The drill stations should be so made that the men on a steaming watch remain at their work, while the water-tight doors, fire-hose, &c., are cared for by their first or second reliefs.

The number of machinists allowed will ordinarily provide for a detail of them to be put in charge of the piping and valves in the fire rooms, and of the auxiliary machinery outside of the engineer department. Skilled men, and not coal passers, should be stationed at and run the ice machines and distilling plant.

If possible there should be a fireman or coal passer from each division assigned to assist the yeoman in issuing and caring for the stores, so that when under way there will always be at hand a man familiar with the location of any tools or stores needed in a hurry.

Instead of having the force divided into four sections, the usual arrangement into three divisions seems preferable. The men in each division being equally divided between the port and starboard compartments, allows of the force being readily put into two watches when required, by sending to duty below of the division longest off watch the men stationed ordinarily in either the port or starboard compartments, and then using them where required to equalize the force on watch in the different compartments.

In order to keep everything in good condition, there should be a systematic overhauling of all machinery, compartments, &c., at stated times; and to provide for remedying defects as they occur, a book should always be kept in the engine room in which should be entered any defect or item requiring attention in any part of the department, with the name or initials of the person reporting it, so that the defect can afterwards be readily located. From this book the chief engineer should make out the daily list of work, stating which machinist or other leading man is to be put in charge of the job, and upon the completion of the job such machinist or leading man should be required to report its

completion to the officer on day's duty and also to initial the job as being completed by him, in order that the responsibility can be placed in case of careless work developing later.

[NOTE.—All discussions of this article which are received too late for publication in this number of the JOURNAL will be published in the succeeding number.]

THE ARRANGEMENT AND EQUIPMENT OF SHIPBUILDING WORKS.

By Mr. James Dunn, of London.

[Paper read before the Institution of Mechanical Engineers.]

Rapidity of production and economy in construction are the two great desiderata of modern shipbuilding. Competition is sufficient explanation of the latter requirement; while a shipowner, although he may take months in which to make up his mind to place an order, accompanies his valued communication with commands as to delivery, and, like Kipling's Midshipman, the shipbuilder "must do what he is told—not immediately, but sooner, much sooner." But even a cursory examination into the economics of manufactures convinces one that rapid construction of itself means economical work, for that which insures the one promotes the other. Modern mechanical appliances, which facilitate and economize work, tend also to reliability in the result; for apart from the influence upon the worker of the precision of machine tools, with their gages, there is in the end a higher remuneration for a given job, since less time is taken, and thus there is less temptation to "scamp" work. This latter is more prevalent where the process is purely manual and of long duration.

In the arrangement and equipment of shipbuilding works, primary consideration must therefore be given to rapidity in construction, consistent always with a due appreciation of the possibilities of earning profit on the capital involved; this latter is of importance, because ideals are usually expensive. For instance, no one will gainsay the great economic advantage of practically completing a ship within a graving dock, because all heavy parts of the structure may be moved by portable cranes to their exact position within the ship; whereas with a ship in

a fitting-out basin and a fixed crane, the ship must be moved—a process which, in the case of a ship of 10,000 or 11,000 tons displacement, is costly and troublesome. Many may thus consider that the ideal establishment is a shipbuilding yard whose berths are all, or nearly all, graving docks, permitting the vessels to be completed with the help of gantry or cantilever cranes traveling on the dock walls, the necessary workshops being in juxtaposition, so as to minimize the distance through which material has to be traversed. A graving dock, however, involves a capital expenditure of quite £100,000, and the interest and depreciation would thus become a heavy charge which might exceed the resultant saving. Moreover, it is not always possible to have even a limited number of berths filled with ships of great labor value, so that a compromise must be made, and a fitting-out basin as well as a building slip becomes necessary.

General Principles Dominating the Plan of Shipbuilding Works (Fig. 1).—The nature of the site available influences the arrangement of the works, but the general principle dominating the plan is that the various departments must be arranged in relation to the ship at radii increasing in direct proportion to the lessening importance or volume of the work turned out by the respective shops for the ship when on the building slip, or when at the fitting-out basin. Thus, the platers, angle-iron and beam workers, must necessarily occupy the closest position to the ship; beyond them would come the joiners and woodworkers generally, while in the third zone there would be the light-iron and copper constructors, with various other departments, as, for instance, upholstering, decorating, &c. It is desirable, too, that the engineers and boilermakers should not be far removed, for as much as possible of the machinery weights should be put on board a ship before it is launched. A new set of conditions arises when the ship is at the fitting-out basin; then the minimum of steel structural work remains to be done, while the cabin fitting, decoration, and engineering work predominate.

Fig. 1 is a plan of the Naval Construction Works of Messrs. Vickers, Sons and Maxim, at Barrow-in-Furness, first laid out by the late Mr. Robert Duncan, of Port Glasgow, upon such a well-

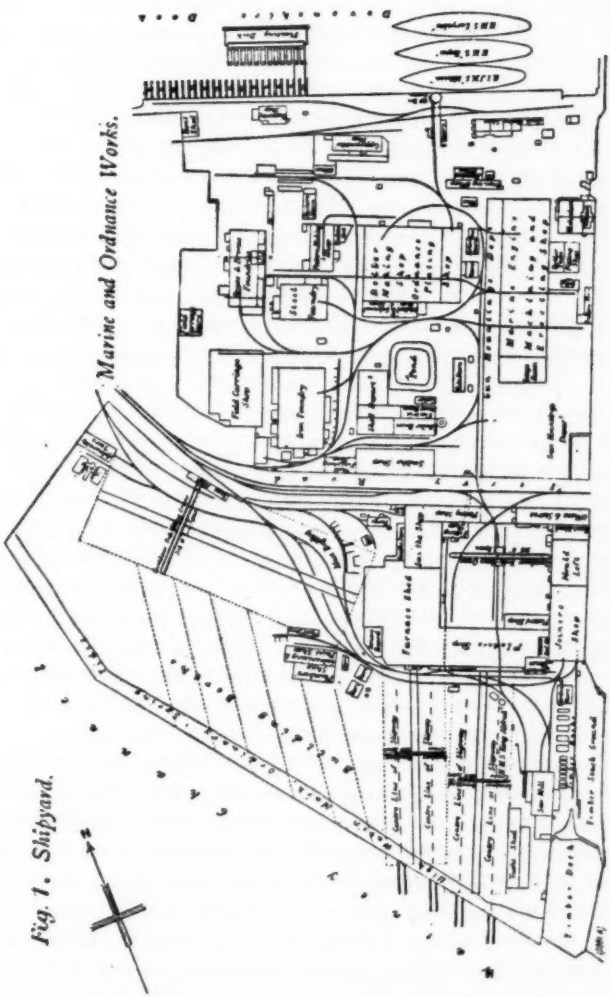


Fig. 1. Shipyard.

defined and liberal plan that, notwithstanding great expansion during the past three years, there has been no need to depart from the general scheme, which will be recognized on all hands as admirable, even in the light of present-day experience. In the shipbuilding yard (the section of the works to the north of the Ferry Road) the main buildings form a quadrangle, the space within which serves admirably for stacking the plates, &c. The range of shops close to the building slips are occupied by the scrieve boards, angle and plate furnaces, bending blocks, and angle, beam and plate-working machine tools, and these are arranged so that the steel structural material passes from the quadrangle through the respective departments in a clearly defined direction, handling being reduced to a minimum. The wood department is confined to the eastern side of the quadrangle, the timber being passed through the saw mill to the "racks" or to the shops, while the joiners', carpenters,' boatbuilders' and block and tacklemakers' departments (embraced in the one building) have direct communication with the building slips. Again, the galvanizing, plumbers', smiths' and engine-fitters' shops, to the west of the quadrangle, are all arranged as near to the building slips as the steelworkers' department will admit. For new building berths there is available ground to the northwest, and as a separate entrance for material coming by railway has been arranged, along with stackyard and cantilever traveling crane for distributing the steel, it will only be necessary to add steelworkers' machine sheds to the west, still retaining the furnaces and bending blocks in the central position.

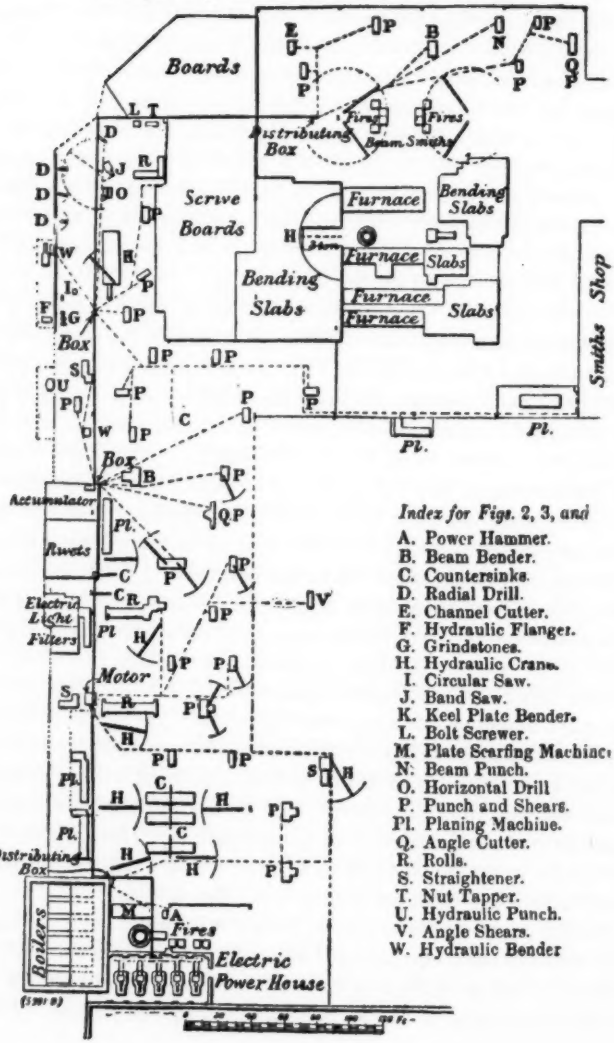
The site available, tidal influences, and the harbor plan largely influenced the relative positions of the engine works and the shipbuilding yard, but the result attained is distinctly satisfactory. The engineering department, with the shipbuilding yard, together form an oblong on plan, the fitting-out basin being at the one end and the building slips at the other. As the maximum of steel structural work is done before the ship is launched, the amount of time lost in transit, both of workers and material, is very small in this important department. This is assisted also by the various departments engaged in the ultimate completion

of the ship having workshops close to the fitting-out basin, and also by having on board the ship many portable machine tools, so that the movement of men and material between the shipyard and the fitting-out basin is comparatively small. Indeed, careful calculation has shown that the loss involved in this way at the Barrow Works is probably only about one-sixteenth of 1 per cent.; in an establishment where the ships are fitted out at a distance of about half a mile from the works, the loss for transit has proved in one actual case to be 4.6 per cent. on the work done at the fitting-out basin. This practice of completing the vessel away from the shipbuilding base is a common practice both on the Clyde and on the Tyne.

The Electric Driving of Machine Tools (Fig. 2).—Turning now to the arrangement and driving of tools, a plan of the plate, angle, and beam tool shops is given (Fig. 2) which shows also the position of the electric-power station and circuits. Importance, from the economical point of view, must be attached to the electric driving of machine tools, and at the Naval Construction Works the installation is very complete. The power station consists of five generating sets, the total horsepower being 1,250, and the electrical capacity 750 kilowatts; but in the engineering and gun-mounting department the power plant is of 2,500 horsepower and 1,500 kilowatts capacity, and electrical connection is established between the two departments. These stations are utilized both for power and lighting purposes, the voltage of the direct current being 210 with 3,570 ampères in the shipyard department and 7,150 ampères in the engineering works. As to the economy of the electrical system, the coal consumption over a given period of average working conditions is only one-third what it was for steam driving; but the interest and depreciation of the electric equipment must be taken into consideration. This, however, is not likely to equal the coal economy, while there is the additional advantage of direct control over the motors.

As the power necessary for the various types of machine tools was most carefully investigated when the system was introduced, it may be useful to the members of the Institution to have a list of the machinery in the shipbuilding yard, with a note of the

Fig. 2 —*Plate, Angle, and Beam Tool Shops in Shipyard. Arrangement of Electric Power Station and Circuits.*



Index for Figs. 2, 3, and

A. Power Hammer.
B. Beam Bender.
C. Countersinks.
D. Radial Drill.
E. Channel Cutter.
F. Hydraulic Flanger.
G. Grindstones.
H. Hydraulic Crane.
I. Circular Saw.
J. Band Saw.
K. Keel Plate Bender.
L. Bolt Screwer.
M. Plate Scarfing Machine.
N. Beam Punch.
O. Horizontal Drill
P. Punch and Shears.
Pl. Planing Machine.
Q. Angle Cutter.
R. Rolls.
S. Straightener.
T. Nut Tapper.
U. Hydraulic Punch.
V. Angle Shears.
W. Hydraulic Bender

power of the electric motors installed for each tool, and this will be found at Appendix I. Where the tools are conveniently situated for driving from shafting—as a rule where belt drive was formerly adopted—the shaft has been retained, and a large electric motor conveniently placed for running it. This secures any advantage from stored-up power in the pulleys to assist in starting drills and cutting tools generally, while at the same time a less power of motor is possible, since all the machines are not likely to be simultaneously doing their maximum duty. In the machine shed, however, the majority of the tools have independent motors, the largest being 45 horsepower, operating plate-bending rolls 30 feet long, to take in armor-deck plates, while there are several cases of from 30 to 20-horsepower motors.

Many of the motors drive their machine tool by belting, with belt-striking gear for reversing. Some of the punching and shearing machines, however, are driven by spur gearing, the pinion on the motor spindle being of soft material, to deaden the shock and reduce the vibration. In such cases the motor is itself reversible. In a few instances, for large mangle rolls, angle shears and angle-beveling machine, a chain belt covered by a gear case is used.

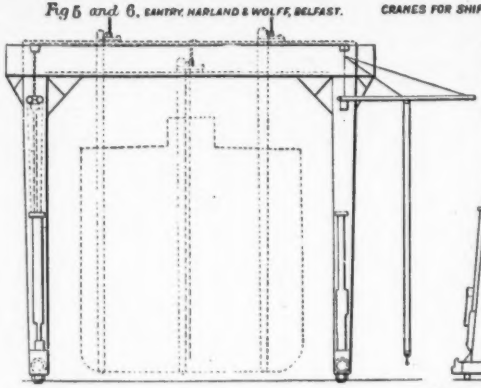
As to the speed of the motors, all above 5 horsepower run at 600 revolutions per minute, the interposition of belt pulleys enabling the speed of the various machine tools to be reduced to the required rate of rotation. Motors of 3 horsepower, which are used for drilling, countersinking, joiners' saws, &c., are run at 850 revolutions. The 2-horsepower motors, of which there are three or four, run at 1,200 revolutions per minute, two $1\frac{1}{2}$-horsepower motors make 1,100 revolutions per minute, while several 1-horsepower motors, used for grinding, for saws and for several portable tools, make 1,300 revolutions per minute.

The Arrangement of Machine Tools in the Platers' Shed (Figs. 2 to 4).—The arrangement of the tools generally is indicated on the plan of the plate, angle and beam tool shops (Fig. 2). It will be seen that beams are worked on separate slabs and machined to the west of the furnaces, angles to the south, and plates in the main shop.

Figs. 3 and 4 show more fully a typical arrangement of machine tools in the platers' shed, and dotted lines and arrow heads indicate the direction of the plate or beam through the machines. The plate, it will be seen, enters from the quadrangle at *A* (Fig. 3), and passes to one or other of three large punching machines *P*, where it is also sheared, going next to a plate-edge planer *Pl*, to the counter-sinking machine *C*, and finally through the rolls *R* to the railway having direct communication with the building slips. The direction of the beam is also defined through the angle cutter *Q*, beam punch *P* and bender *B*. A similar diagram (Fig. 4) shows in another group of tools the same wide area around the tools to ensure that the work at one machine may not interfere with the operations at another, while heavy plates can be transferred by cranes successively from one machine to another, being delivered ultimately close to the ship. It is of great importance to have cranes of wide radii and other plate-shifting facilities. It is just possible that in this department an improvement could be effected in the handling of plates by the adoption of the system in use for a similar purpose in some of the rolling mills of the United States. Small posts are placed at occasional intervals in the rolling-mill shop floor, having casters or rollers at the top arranged to swivel in every direction; the system has been aptly described as corresponding to tables inverted, so that the casters on the legs are uppermost. With such an arrangement of uprights the plate could easily be run from one machine to the other, or from end to end of the platers' shop by the gang of men working it through its successive operations. The level at which the plate is fed into the several machines would require to be exactly the same in all cases.

Some Large Machine Tools.—It is scarcely necessary to say that at the Naval Construction Works every conceivable type of ship is built, and Messrs. Vickers, Sons and Maxim have therefore installed very powerful tools. There are at the works a set of mangle rolls to take plates up to 6 feet wide, also rolls for straigthening and shaping plates 30 feet long, the large top roller being elevated and depressed by an electric motor at each end, while the driving and reversing of the machine is done by a 45-horse-

Fig 5 and 6. GANTRY, HARLAND & WOLFF, BELFAST. CRANES FOR SHIPBERTHS



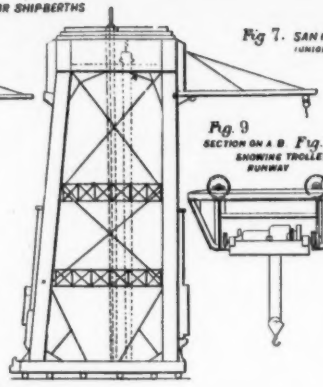


Fig 7. SAN FRANCISCO. (UNION IRON WORKS).

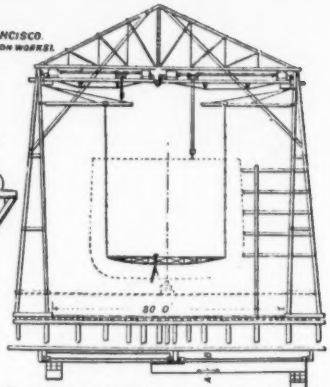


Fig 9
SECTION ON A B
SHOWING TROLLEY RUNWAY

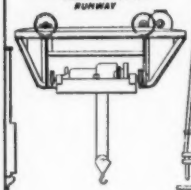


Fig. 15.

Fig 8 TRAVELLING CRABS OVERLAPPING (HELLMAN SCHEME)

Scale for Figs. 5 to 8.

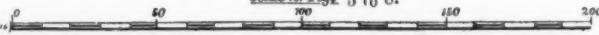


Fig. 10 VULCAN WORKS, STETTIN

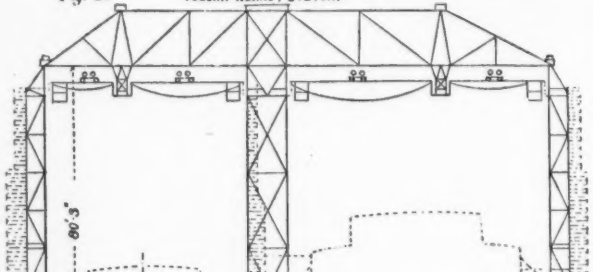
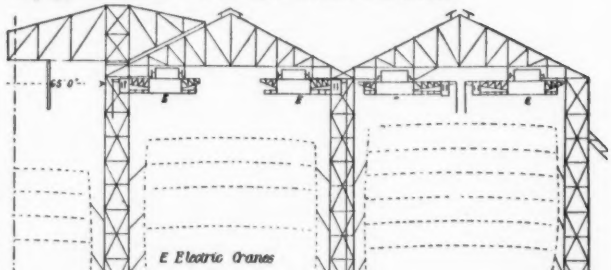


Fig. 11 CLOSED IN BERTH. SWAN AND HUNTER, LOW WALKER ON TYNE



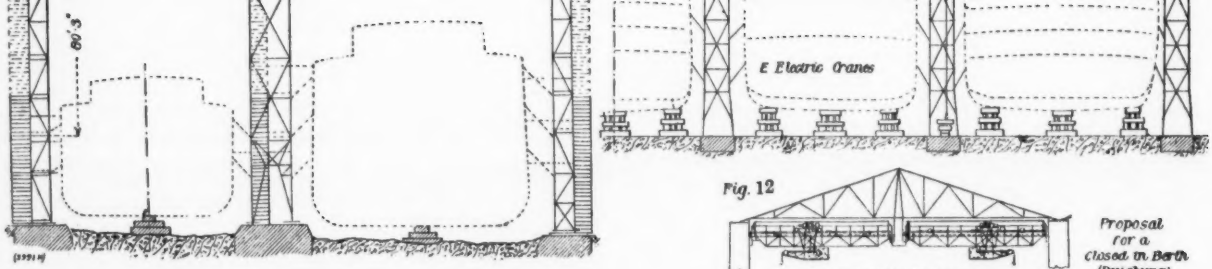
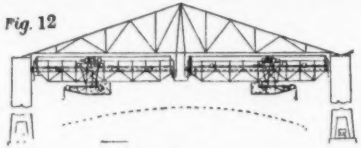


Fig. 12



Proposal for a closed in Berth (Duisburg)

Fig 13 CANTILEVER CRANES FOR SHIP BERTHS (BROWN) BARROW.

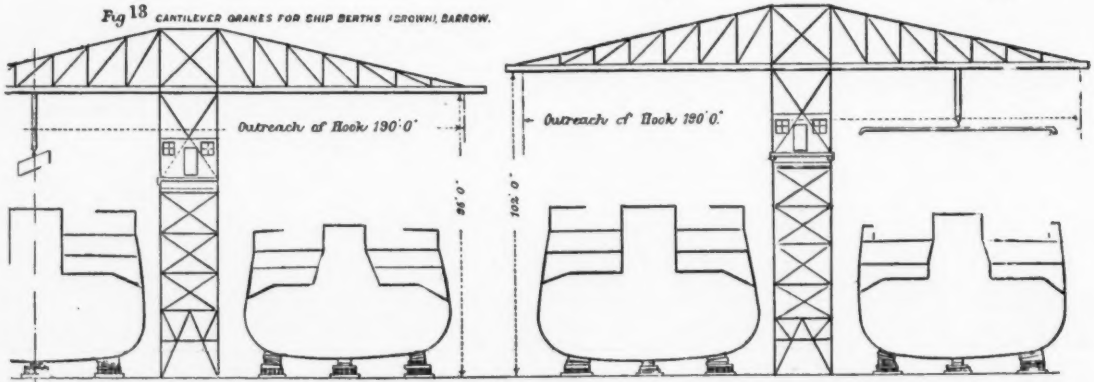


Fig 14 CANTILEVER CRANE (!!)

PLATE YARD, BARROW.

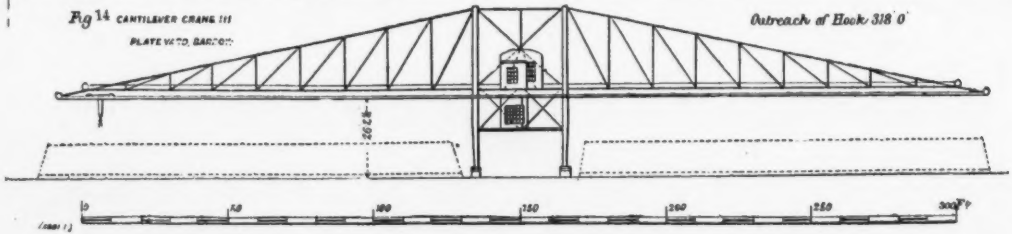


Fig.3. —*Arrangement of Machine Tools in Platers' Shed, Shipyard.*

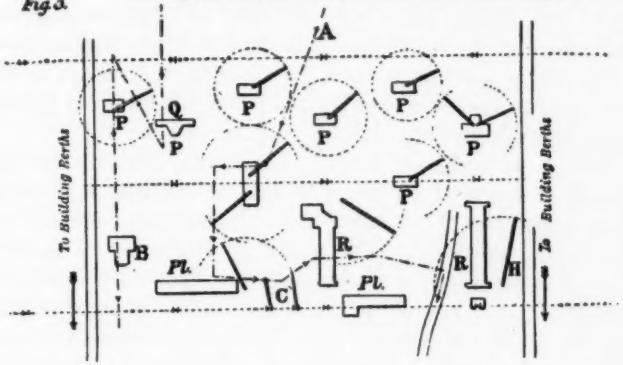
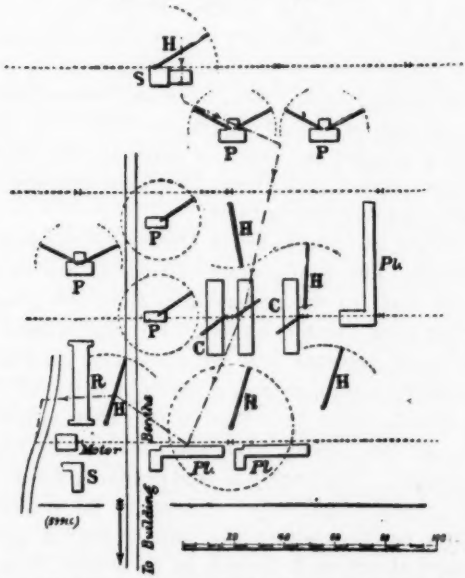


Fig.4. —*Another Arrangement.*



Dotted line with arrow heads indicates the direction of Plate or Beam passing through the machines.

power motor with a reversing switch. There is an hydraulic bender and flanger fitted with cylinders of sufficient power to bend—when cold—plates $\frac{7}{8}$ inch thick and of any length up to 32 feet, and a scarfing machine for tapering ship plates at the edges so that they may overlap, to obviate the fitting of tapered liners, three-ply riveting and the caulking of same.

There is an hydraulic machine for cutting channels and angles; it is operated on the principle of the hydraulic press. There is also one or two other hydraulic machines, notably one for punching manholes. The hydraulic power for all tools in the yards is developed in a separate power plant working up to a pressure of 1,600 pounds to the square inch. In appendix I a complete list of the principal tools within the shipbuilding yard is given, and no further reference is here necessary.

Closed-in v. *Open Shipbuilding Berths, and the Cranes Serving Them* (Figs. 5 to 12).—The increase in the size of ships, the greater weights of the units now used in construction, and the extension of the practice of countersinking, riveting and caulking by portable mechanical tools, have necessitated an improvement upon the old method of rigging up derricks alongside the ship for lifting weights on board, or carrying the tools. Many systems for accomplishing this end have been adopted, and most have advantages to commend them.

One of the first was that in use at Messrs. Harland and Wolff's (Figs. 5 and 6). The gantry crane illustrated has a clear headway from rail level to the underside of the cross girders of 98 feet, while the clear width is 95 feet. For the purpose of lifting weights on board, separate jibs are carried on each of the four corners of the structure, swinging through an angle of 180 degrees, and able to place their load of four tons within the shell of the ship, 40 feet distant from the axis of the jib, without moving the crane. The gantry is used primarily for the carrying of hydraulic riveters, and only incidentally for traversing with loads to their position within the ship, so that it would seem that this large structure is limited in its utility. For carrying the hydraulic riveters there are three hydraulic traveling cranes running on the cross girders, two of them on the upper and one

on the lower boom, an arrangement which enables two riveters to be brought closely together. In the building of the *Celtic* the heaviest weight carried by the traveling-crane gear was understood to be the hydraulic riveters of $7\frac{1}{2}$ tons, and the heaviest weight lifted by the jibs was $3\frac{1}{2}$ tons; at the Barrow Works 15-ton loads are dealt with in building warships on the slip. With their gantry Messrs. Harland and Wolff were enabled to rivet expeditiously and economically the top-sides and keelplate, the center plate, the tank intercostals, and flange-plate frames, and the upper-deck stringers in the *Celtic*, while similar work is done on other large ships. The thickness of the plating may also be given in connection with the weights requiring to be dealt with in large merchant work; the shearstrake plates of the *Celtic* were $1\frac{1}{4}$ inches, side plating $1\frac{1}{8}$ inches to 1 inch, the bottom plating 1 inch, and the keelplate $1\frac{3}{8}$ inches.

The system carried out at the Union Iron Works at San Francisco is shown in Fig. 7. Here there are overhead cranes traveling the full length of the building berth, and a series of independent jibs for carrying the girder on which the hydraulic riveter is supported. This involves an extensive structure, the foundations of which on either side limit the number of shipbuilding berths for a given width. The berth is not closed in, but the number and the great sectional area of the trusses for supporting the traveling crane affect the lighting of the berth. These trusses, with their supporting posts, are placed at 12-foot centers; the uprights are utilized for the staging, and they carry, with the use of suspension rods, a jib on which a trolley runs for supporting the girder carrying the riveting machines. The girder and riveters have to be moved from one pair of the jibs to the other, as required. The weight of the heavier riveters in use is only 1,400 pounds, to work $\frac{7}{8}$-inch rivets with a 30-inch gap. The traveling cranes have a lifting capacity of 5 tons; the speed longitudinally is 180 feet per minute, horizontally 90 feet, and for elevating 90 feet. The structure seems elaborate for the duty done. This system of two cranes placed alongside each other involves a considerable increase in the strength of the truss at the center to support one-half of the crane and its load. In the

case of the San Francisco structure another objection has been ingeniously overcome; usually the two cranes are equal in length, and because of their supports there is a considerable space at the center line of the berth—just over the keel—right fore and aft, over which the crane has no direct control. But, as will be seen from Fig. 7, the apex of the truss is 3 feet from the center line, and thus the crane to the right of the section is 6 feet longer than the other, and commands the keel. At the same time there is still a small section of the width of the ship which is not commanded by the cranes overhead.

Fig. 10 illustrates a structure which has been erected quite recently at the Vulcan shipbuilding yards at Stettin, and here also the cranes are made of different lengths. The structure is of steel work without roofing, and the motors are electrically driven. Each crane lifts 4 tons, and the speed of longitudinal traverse is 262 feet per minute.

Neither the berth at San Francisco nor either of those at the Vulcan Works in Germany is closed in, and in this respect they differ from the arrangement adopted by Messrs. Swan and Hunter, who, like one or two foreign firms, prefer that the berths should be roofed over, as shown in Fig. 11. There are advantages in such arrangement where severe weather conditions obtain, especially where the snowfall is considerable or the rain incessant for long periods; but apart from the great cost, in view of the loads to be supported, there is always the disadvantage of restricted light, because glazing cannot always be kept clean, and artificial light is at best a poor substitute, and the general result may be conducive to idleness. There is also the probability of drafts, and, although it is said that this has not been experienced to any great extent at Messrs. Swan and Hunter's, experience of wind-swept Barrow suggests that this solution might involve inconvenience and discomfort. It is claimed for these structures that there is a saving in the cost of shoring and fairing the vessels, but such saving need not be confined to this particular form. Messrs. Swan and Hunter have provided large horizontal jibs to their traveling cranes, which revolve below the cranes, but withal there is a gap in the center line. The outside

crane of the cantilever type commands a space 500 feet in length and 65 feet in breadth.

Fig. 12 illustrates a German design for building berths. Here also the jib is carried below the main traversing crane, being suspended in a ball-bearing; the horizontal pressure is taken up by live rollers. The lifting gear consists of a double set of spur-wheels and a rope drum with turned grooves. The crane has a capacity of 3 tons, the lifting speed being 66 feet per minute, the longitudinal traverse 197 feet per minute, the horizontal traverse 108 feet per minute, and the rotating of the horizontal jib 295 feet; the lifting motor is of 20 horsepower, and the motor for horizontal traverse 13 horsepower. But here again the load is comparatively limited, and there are between 4 feet and 5 feet in the center of the ship which are not commanded by the crane.

These overhead systems generally involve a light-excluding structure over the ship; and, most important of all, the maximum weight lifted is not great. While they give the advantage of two cranes for each ship, these are limited in their radius across the ship, although this may not be a serious objection, especially with twin-screw steamers. The Wellman-Seaver Engineering Company, of Cleveland, Ohio, who have fitted in some American lake yards gantry cranes of the cantilever type corresponding in general arrangement to the Brown system, have made an arrangement overcoming this difficulty by overlapping the traveling cranes, and supporting the lifting trolley on the lower flange of the girders forming the travelers (Figs. 8 and 9).

Cantilever Cranes at Barrow (*Brown*) (Figs. 13 and 14).—The system which has been adopted at the Naval Construction Works at Barrow-in-Furness is that known as the Brown patent balance cantilever type, and a section of the building berths is shown on Fig. 13. This system consists of a light trestle work placed between two shipbuilding berths, on which there travels a crane whose cantilever arms stretch over the ship on either side of the trestle. The trestle for one of the cranes is 729 feet long, and it will be some time before ships exceed this length; the other is 647 feet, and both can easily be extended at any time without even temporary inconvenience. The whole of the ship is imme-

diately under the control of the crane hook, the total span or outreach of the hook being 190 feet, while the clearance above the deck structure is equal to the depth of the ship itself. The same principle is applied for dealing with the plates, timber, &c., at the part of the works where the material is stored, as shown on Fig. 14, the outreach of the hook being 318 feet.

In the design of the Brown cranes as fitted at Barrow the wind area was reduced as much as possible so as to minimize the material for a given maximum strength. This also lessened the cost and incidentally admitted the fullest measure of daylight. The trestle has also been designed to avoid interference with operations along the side of the ship. The uprights are all attached to their foundations, and to the cross connections at the top by pin joints, so that the entire structure may expand or contract longitudinally. The members of the structure are held vertically by the center panel of the trestle, which consists of a large A brace extending upwards from the foot of one column to the center of the panel and down to the foot of the other column. The only possible interference with the work alongside of the ship is at the uprights where the ship attains its maximum breadth, and even here it is small.

The crane is worked by one 85-horsepower electric motor with suitable gearing for the several movements. For traversing the crane along the track on the trestle, power is transmitted through bevel gears and shafting to the driving gears on the truck, which is controlled by suitable breaks and clutches. The trolley travel along the cantilever arms is accomplished by the revolving of two drums winding wire rope connected to the trolley. These two drums are on one shaft which runs always in the same direction. When one drum is thrown into gear with the driving shaft the other is disconnected and remains idle, so that while one winds the other "pays out." The drums are kept in the same relative position to one another by the use of a return loop or a small wire rope, which is wound in an opposite direction to the ropes connecting the trolley. The hoisting is accomplished by a single drum; the lowering is through

gravity alone, governed by brakes. The speeds vary according to load, with the following minima and maxima:

	Feet per minute.
Hoisting	100 to 600
Trolley or transverse traveling	400 " 800
Track or horizontal travel	400 " 700

The cranes lift 10,000 pounds (4½ tons) at the extreme travel of the trolley, and 30,000 pounds (about 13½ tons) at a distance of 60 feet from the center of the crane. The resultant force of the crane under the load is kept within the proper limits by the use of a counterweight running on a track along the cantilever arms and above the track on which the hoisting trolley travels. It is connected by ropes to the trolley, so that whatever may be the position of the hoisting trolley on one arm of the crane, the counterweight is at the same time automatically brought to a similar position on the other arm. For extra heavy loads there is an additional weight which is added with little trouble to the normal counterweight of 4,000 pounds. To raise heavy loads at 60 feet from the center the counterweight is adjusted so that instead of being 60 feet it is 90 feet from the center, or at the extreme of the opposite arm. This is easily accomplished; the trolley is brought to the center of the crane, and the counterweight automatically also comes to the center; the counterweight is then unclamped from the ropes which connect it to the traveling trolley and the trolley moved out 30 feet on the cantilever opposite to that on which the heavy load is to be lifted, and the counterweight is there re-clamped. This operation occupies but a minute or two. Thus, when the lifting trolley travels to the load it passes through 90 feet in coming from 30 feet on one side and going to 60 feet out on the other arm where the load has to be raised. The counterweight naturally travels simultaneously through its 90 feet, which will be from the center to the extreme of the arm opposite to the load. Thus the full lever arm is utilized and the full effect of counterweight obtained.

Fig. 14 illustrates one of the cantilever yard cranes. The main point to be noted in the construction of these cranes is the open trestle structure, allowing pieces of 60 feet in length

to be carried through the pier without turning. To avoid twisting there have been adopted what really amounts to two trolleys, which carry their loads to two points, and which travel at exactly the same speed. Actually, however, these two blocks form part of a single trolley which is operated by two drums. The rope system employed is somewhat complicated. The capacity and dimensions of the yard cranes are as follows:

Trolley travel 159 feet 1½ inches each way from the center of the crane, or, in other words, a total of 318 feet 3 inches center to center of the extreme position of the hoist block.

The maximum load is 11,000 pounds (5 tons), which can be lifted and traveled through the entire length of the travel of the trolley on the runway.

The double tracks on which these cranes run are gaged 30 feet 6 inches center to center.

The power which is necessary to run one of these cantilevers is 85 horsepower arranged for 200-volt tension direct current.

The motor will lift the maximum load, 11,000 pounds, at the rate of 200 feet per minute, will traverse the crane along the tracks at about 300 feet per minute, and travel the trolley to any desired speed up to 750 feet per minute.

The high speed of horizontal and longitudinal traverse of the cantilever system in operation at the Barrow Works more than compensates for the duplication of cranes in the instances already indicated.

The Utility of Building-Berth Cranes.—It will be seen that these cantilever berth cranes serve all the purposes for lifting material on board, while as regards the supporting of hydraulic riveters for double-bottom and keel-strake work, the usual method of gantry running on the inner bottom or flooring of the ship will, as formerly, be applied. For supporting the riveter for working the bilge and sheerstrake there is no reason why jibs should not be carried on the trestles of the cantilever cranes and on special uprights on the offside of the ship; the pneumatic tools for riveting, caulking, &c., are easily supported upon the deck beams because of their light weight.

The primary consideration was to secure a wide radius of ac-

tion and a reasonably large lifting power at high speed, because of the important desiderata which were indicated at the commencement of this paper, and particularly because of the economy which results from the lifting of as much of the machinery and internal equipment on board while the vessel is on the slip. Thus, for instance, it becomes a simple matter in the future to put on board quickly, and thus economically, all auxiliary machinery, the greater part of the water-tube boiler equipment, the bedplates of the main engines, the shafting right up to the thrust block, and many other details. It is true that part of this work has been done in the past, but it has been accomplished at considerable cost with temporary sheerlegs, which had to be moved from time to time. The principal limiting condition to the work done before floating the ship is the ultimate weight to be launched. In the first place, there is the load on the launching ways, which has not hitherto exceeded to any extent 3 tons per square foot, but it is more frequently less than $2\frac{1}{2}$ tons, so that there is, from this point of view, still some possibility of increase. Again, the dip of the stern of the ship at launching is a determining factor. At the launching ground at Barrow, however, there is sufficient margin for carrying out the ultimate aim.

Work Done on Various Types of Ships Before and After Launching.—As to the condition of the work at the date of launch, some data applicable to various types of ships have been collected from works where the practice does not materially differ. The data are given in Table I, subjoined. This table gives the total number of men-hours involved in the construction of various types of ship, divided between the shipyard and engineering departments, and although not germane to the immediate subject in hand, it is interesting to note that, whereas with armored war vessels the number of men-hours per ton of totalled finished weight of the ship varies from 678 to 722, the proportion in the case of the fastest of the merchant steamers carrying a large number of passengers is only $401\frac{1}{4}$ men-hours per ton weight of the finished ship, while in the case of the purely cargo-carrying steamer it is 240 men-hours per ton weight of the ship. In other words, for a first-class ironclad the number of men-hours is about

TABLE I.—LABOR INVOLVED IN THE CONSTRUCTION OF VARIOUS TYPES LAUNCHING, IN SHIP AND

——	I. Warship No. 1.	II. Warship No. 2.
Dimensions	*length. breadth. depth.* 435′ × 69′ 3″ × 39′ 9″	*length. breadth. depth.* 435′ × 69′ 3″ × 39′ 9″
Gross tonnage	7,056	7,056
Crew	677	677
Passengers	.....	.....
Indicated horsepower	16,800	18,200
AGGREGATE WORKMEN-HOURS ON SHIP.		
Shipyard department	4,344,147 hours.	4,290,168 hours.
Engineering department	1,623,837 hours.	1,891,893 hours.
Total	5,967,984 hours.	6,182,061 hours.
Percentage of shipyard department to total	72.8 per cent.	69.4 per cent.
Percentage of engineering department to total	27.2 per cent.	30.6 per cent.
Men-hours per ton of builders' finished weight: Hull	520½	501
Men-hours per ton of builders' finished weight: Engines	194½	221
WORK DONE BEFORE LAUNCHING.		
Total number of men-hours, in both ship and engine works	3,083,348 men-hours.	3,159,634 men-hours.
Total number of hours on engine and boiler-room work prior to launch	44,527 hours.	53,226 hours.
Percentage of engine and boiler work to the total work before launch	1.4 per cent.	1.7 per cent.
Percentage to total of engine and boiler-room work requiring to be done to complete machinery	2.7 per cent.	2.8 per cent.
Launching weight	6,370 tons.	6,520 tons.
Builders' finished weight (including machinery)	8,350 tons.	8,560 tons.
Percentage of lauching weight to builders' finished weight	76.3 per cent.	76.2 per cent.
Condition of ship at launch	Iron and steel work practically complete. All armor complete. Decks complete. Joiner work half complete. Plumber work three-fourths complete. Propellers and tunnel shafting on board.	Iron and steel work practically complete. All armor complete except conning tower. Decks complete. Joiner work half complete. Plumber work three-fourths complete. Propellers and tunnel shafting in place.
WORK DONE AFTER LAUNCH.		
Total number of men-hours after launch: Shipyard	1,305,326 men-hours.	1,183,760 men-hours.
Total number of men-hours after launch: Engine works	1,579,310 men-hours.	1,838,667 men-hours.
Percentage of ship work to total work done	45.2 per cent.	39.1 per cent.
Total number of hours of shipyard men after launch	1,305,326 hours.	1,183,760 hours.
Percentage to total of shipyard hours	30.04 per cent.	27.5 per cent.

OF VESSELS; AND THE PROPORTION OF LABOR DONE BEFORE AND AFTER ENGINEERING WORK RESPECTIVELY.

III. Armored warship No. 3.	IV. Merchant ship.	V. Merchant ship.	VI. Merchant ship.
length. breadth. depth.	*length. breadth. depth.*	*length. breadth. depth.*	*length. breadth. depth.*
390′ × 74′ 3″ × 43′	440′ × 54′ × 36′	345′ × 42′ × 25′ 8″	500′ × 55′ × 37′
8,700	6,514	3,080	7,945
750	84	52	200
.....	17	74	592
13,500	2,000	2,270	9,140
5,224,309 hours.	785,905 hours.	582,752 hours.	2,382,353 hours.
1,653,011 hours.	353,541 hours.	219,217 hours.	928,297 hours.
6,877,320 hours.	1,139,446 hours.	801,969 hours.	3,310,650 hours.
75.9 per cent.	68.9 per cent.	72.6 per cent.	72 per cent.
24.1 per cent.	31.1 per cent.	27.4 per cent.	28 per cent.
515	165½	227	288¾
163	74½	85½	112½
3,705,537 men-hours.	584,381 men-hours.	550,932 men-hours.	1,273,175 men-hours.
95,439 hours.	16,156 hours.	23,852 hours.	36,418 hours.
2.5 per cent.	2.7 per cent.	4.3 per cent.	2.8 per cent.
5.7 per cent.	4.5 per cent.	10.9 per cent.	3 9 per cent.
7,460 tons.	3,750 tons.	2,120 tons.	5,440 tons.
10,140 tons.	4,740 tons.	2,566 tons.	8,250 tons.
73.6 per cent.	79.1 per cent.	82.6 per cent.	65.9 per cent.
Iron and steel work practically complete. Side armor on both sides complete. Screen bulkhead forward and aft and lower portion of barbette armor forward and aft complete. Upper portion of barbette armor and conning tower not fitted. Casemates Nos. 1, 2 and 5 on each side not in place. Decks complete. Joiner work half complete. Plumber work three-fourths complete. Propellers and tunnel shafting on board.	Iron and steel work practically complete. Wood decks, with exception of flying bridge and deck-house tops, all laid. Joiner work very little done. Propellers and tunnel shafting, thrust shaft, thrust blocks, and most of the auxiliary machinery on board.	Iron and steel work practically complete. All decks laid and joiner work three-fourths complete. Propellers and tunnel shafting and thrust blocks and most of the auxiliary machinery on board.	Iron and steel work mostly complete except building of boat deck, flying bridge, masts, and chart-house. Decks seven-eighths complete, and joiner work about half complete. Propellers and shafting, including thrust shafts and blocks and most of the auxiliary machinery on board. Plumber work about half complete.
1,614,211 men-hours.	217,680 men-hours.	55,672 men-hours.	1,145,596 men-hours.
1,557,572 men-hours.	337,385 men-hours.	195,365 men-hours.	891,879 men-hours.
50.8 per cent.	39.2 per cent.	22.2 per cent.	56.2 per cent.
1,614,211 hours.	217,580 hours.	55,672 hours.	1,145,596 hours.
30.9 per cent.	27.6 per cent.	9.5 per cent.	48 per cent.

six millions, whereas in the case of a passenger steamer of the same total weight when she leaves the builder's yard the number of hours involved is only about one-half, or 3,310,650 hours.

The proportion of work done by the engineering department varies but slightly—from 24 to 30 per cent. of the total. The case of No. 2 warship, where the proportion of engineering work is 30.6 per cent., is exceptional, as here an engineering dispute influenced the figures. Again, in the purely cargo steamer, column IV, the engineering proportion is high—namely, 31.1 per cent.—because the shipbuilding work does not involve any extensive internal fittings, owing to few passengers being carried, while the engine power is as great as in the ship No. 5 in the table.

As to work done before launching, engineers and boilermakers, in the case of five of the six vessels, did less than 2 per cent. of the total; the other instance—that of the ship in column V—approximates more closely to the condition that will prevail for the future at the Barrow Works; for here, as shown in the "condition of the ship at launch," the propellers and tunnel shafting, thrust block, and most of the auxiliary machinery, were on board; but, being a cargo ship, the amount of auxiliary machinery was not by any means so great as is the case in war vessels, and thus the proportion is less than it will be with war vessels. In the case of this vessel in column V, however, 10.9 per cent. of the total engineering work involved was completed before the ship was launched, whereas in the warships the percentage was about 2¾ per cent. There seems no reason why this percentage should not be brought up to about 20 per cent.; for, although the main machinery cannot be "lined up," owing to possible alterations in the form of the ship when afloat, there are many details and loads which come within the carrying weight of the cantilever crane.

The table also shows the extent of the shipbuilding work done prior to the launch and also after the ship has been floated. It is important to reduce the amount that requires to be done after launching, because then the ship is further from the shipworkers' base. Much of the work, it is true, involves little or no weights,

Fig. 15. MACHINE FOR PLANING GUN-ROLLER-PATHS ON BARBETTES.

Cuts 15 Ft. per min.
Feed, ⅛ per rev.
20 Sq. Ft. planed per hour

For 12" and 9·2" Guns.

C - Cutters.

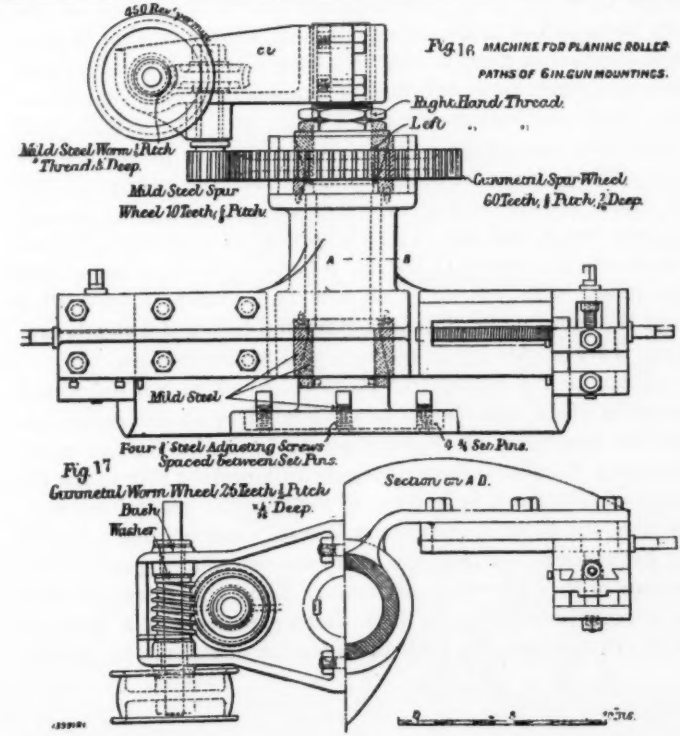


Fig. 16. MACHINE FOR PLANING ROLLER PATHS OF 6 IN. GUN MOUNTINGS.

Fig. 17

so that the question of crane accommodation is not so important. It will be seen that with armored warships the proportion of shipyard work remaining to be done after the launch is between 27.5 and 31 per cent. of all the shipwork; but it varies very considerably in the merchant work, the direct cause being the quantity of joiner and cabinet fittings involved in the completion of the passenger accommodation. Thus, in the case where only 9.5 per cent. of shipwork remained to be done (in the ship given in column V), the joiner work was three fourths completed, and all the decks were laid before the launch, whereas in the ship in column No. VI, where 592 passengers are carried, the joiner work was only half completed, and thus 48 per cent. of the shipyard work remained to be completed after the launch.

Portable Tools Used on Ships, and Methods of Supporting Them (Figs. 15 to 17).—To expedite work on the ship when on the slip and also out in the fitting-out dock, a large amount of portable mechanical plant is used, including a portable electric lighting equipment, an installation of pneumatic riveting and caulking tools, and various electrical drills, etc. A portable tool which may interest the members is the machine for planing the gun-roller paths on barbettes for 12-inch and 9.2-inch guns; this is clearly shown on Fig. 15. It is rotated by a 5-horsepower electric motor, and, with a feed of $\frac{1}{4}$ inch per revolution, the machine cuts at a rate of 15 feet per minute, equal to 20 square feet per hour. Figs. 16 and 17 show a similar machine for dealing with the roller paths of smaller guns of 6-inch and 4.7-inch caliber. This machine is driven by a 3-horsepower motor.

Cranes at the Fitting-Out Basin (Figs. 18 to 22).—Another question which has had to be considered by those responsible for the equipment of shipbuilding works is the type of crane necessary for placing heavy weights on board the ship in the fitting-out basin, and, in addition to showing the general arrangement of the Naval Construction Works' 120 ton crane operated by hydraulic power (Fig. 18), there are reproduced general elevations of four other typical cranes. The heaviest weight lifted in mercantile work within the author's experience is a boiler of over 110 tons weight; with the adoption of water-tube boilers,

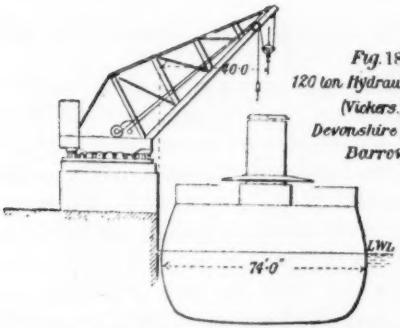


Fig. 18
120 ton Hydraulic Crane (Vickers.) Devonshire Dock, Barrow.

Fig. 19 *100 ton Revolving Crane (Benrath), Bremen.*

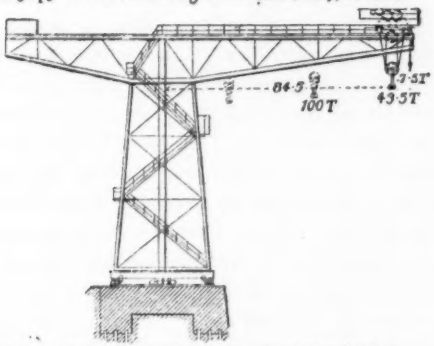
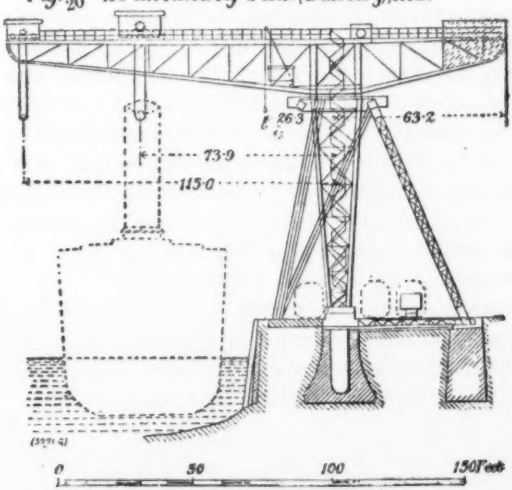


Fig. 20 *150 ton Revolving Crane. (Duisburg), Kid.*

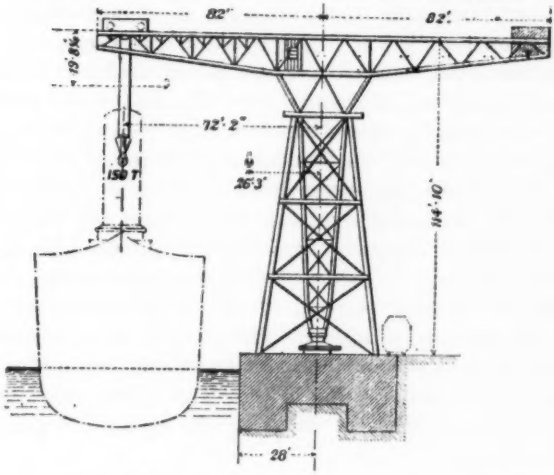


gun mountings and guns now provide the greatest loads in naval work, and these range from 50 to 60 tons.

The modern tendency is in favor of a derrick crane in preference to sheerlegs, because the latter are slow in their movements, work only in one plane, and thus necessitate frequent movement of the ship, while the foundation usually involves trouble because the weight carried is concentrated at two points, each of limited area. Again, the overhang is not greater than with jib or swing cranes, and now that the tendency is all towards an increase in the beam of ships, this latter becomes of primary importance. For instance, in three of the largest works the overhang is 60 feet, 57 feet, and 47½ feet. In this country there are several types of splendid jib cranes, and reference may be made to the two 130-ton steam cranes by Messrs. Cowans, Sheldon & Co., used by Glasgow shipbuilding firms for fitting engines on board their ships, and having an overhang of 45 feet from the face of the quay with the maximum lift. At the dockyards there is a splendid hydraulic crane by Messrs. Tannett, Walker & Co., of 160-ton carrying power, with an overhang from the face of the quay of about 50 feet. Again, quite recently Messrs. Doxford, of Sunderland, installed a jib crane which can lift 120 tons when the jib is commanding a radius of 50 feet, 70 tons for 80 feet radius, and 30 tons for 100 feet radius. But it is of special interest to note what has been done abroad during the past two or three years. Nearly all the works in Germany have been erecting powerful jib cranes in anticipation of the construction of great cargo steamers. Fig. 19 and Fig. 20 illustrate two cranes, the one of 100-ton capacity and the other of 150-ton capacity. Both these cranes are of the horizontal revolving type, which enables the jib to turn a complete circle; so that with a jib of about 180 feet in length (or 120 feet from the central pivot) the radius is very extensive. On the other hand, the clearance above a ship is limited, especially for what are known as the storm-decker steamers, with immense funnels.

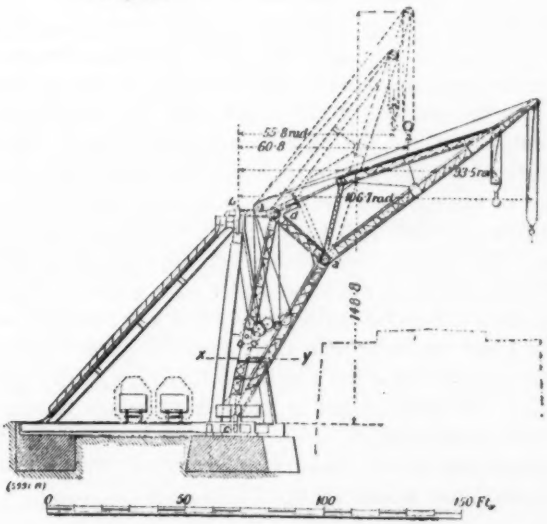
The crane shown by Fig. 19 has been constructed by the Benrath Company, of Düsseldorf, for the Bremen Vulcan Works, and consists of a tower which turns on twelve carriages, each run-

Fig. 21 *150-ton Crane. (Benrath), Bremerhaven.*



100-ton Derrick Crane. (Duisburg), for Bluhm & Voss.

Fig. 22



ning on four rollers, and for rotating purposes four of these carriages are fitted with electric motors of 12 horsepower. The lifting mechanism is also driven by electric power.

The Benrath Company have also constructed a crane for the Imperial Dockyard at Bremerhaven (Fig. 21), with a stationary tower, the vertical axis of which is formed by a revolving pillar, having its bearings in the foundations, and above in the head of the tower. This pillar bears the horizontal jib, which is itself symmetrical as regards right and left; the one arm supports the crab, the other a counterweight. The whole turns through 360 degrees, and the crab moves at the same time, so that the area covered by the crane is equal to a circle whose external radius is 72 feet and internal 26 feet. The rotating power is an electric motor of 26 horsepower; the crab traversing motor is of the same power, and the two hoisting motors of 40 horsepower, working a steel rope 2.4 inches in diameter with differential pulley and double capstan.

Messrs. Krupp's crane, built by the Duisburger Company, shown in Fig. 20, differs in that it has a pyramidal structure which occupies less of the quay's space than the usual crane, as between the legs railway carriages or large loads may easily be passed, as shown in Fig. 20. The chief structure has the form of a three-legged equilateral pyramid, two of whose legs are placed in a line parallel to the quay's edge; the three chief legs are connected at the top by a closed frame, within which the roller path of the crane pillar is fixed; the pillar forms the central axis of the pyramid; it rests on a roller path at the quay level and is provided with a pivot; this roller path has a special bearing. The mechanism which effects the turning of the horizontal jib is placed on the upper roller path, and the jib projects 125 feet from the central axis, and is fitted with two independent winding gears traveling with their respective crabs; the outer gear lifts 45 tons, the other 150 tons; there is a third small lifting crab. The total height is 150 feet 11 inches to the upper edge of the horizontal jib.

A remarkable derrick crane has been constructed for Messrs. Blohm and Voss' works by the Duisburger Company; it deals

with loads of 100 tons, and the radius from the center of the crane for such load is 93 feet 5 inches, giving an overhang in front of the quay of about 65 feet. This crane, which is shown on Fig. 22, lifts its full load at a speed of 4¼ feet per minute, and in addition has separate hoisting machinery for dealing with loads up to 30 tons, the hoisting speed being 13 feet per minute. The great overhang is secured, as in Messrs. Doxford's crane, by arranging that the jib, notwithstanding the great power, can have its inclination altered to a very considerable extent, but in Appendix II, a full description of the crane is given, so that here it is not necessary to enter into details.

The author, in conclusion, wishes to express his indebtedness to several firms who have granted facilities for dealing with the subject, and to many of the members of his staff who have prepared the illustrations.

APPENDIX I.

LIST OF MACHINES AT NAVAL CONSTRUCTION WORKS, WITH POWER OF ELECTRIC MOTORS.

IN MECHANICS' SHOP.

	Motors—H.P.
23 drilling machines to drill from smallest up to 6-inch diameter holes	All these driven from shafting by one 30-horsepower motor.
20 lathes (various), from smallest up to 30 feet long by 4 feet 6 inches in diameter	
5 screwing machines, from smallest up to 2½-inch screws	
1 tapping machine, to tap holes up to 1½ inches in diameter	
2 boring machines, 9 feet long by 3 feet 6 inches in diameter	
4 planing machines, up to 20 feet long by 9 feet high by 10 feet wide	
2 slotting machines, 10 feet long by 6 feet wide and 14 inches stroke	
2 shaping machines, 7 feet long by 6 feet wide 13 inches stroke	
2 milling machines, 3 feet in diameter of tables	
1 grinder for milling-machine cutters	
1 grinder for twist drills	
2 band saws for metal cut up to 17 inches thick	
1 machine for setting teeth of saws	
1 saw-sharpening machine	
2 pairs of 20-inch emery wheels	
2 grindstones	
1 small blowing fan for tool-smith fire	
1 emery polishing machine	
1 gas tempering stove and fan	
2 2-ton traveling cranes	

On Board Ships.

	Motors—H.P.
1 12-inch barbette roller-path facing machine } Fig. 15	5
1 9.2-inch barbette roller-path facing machine } Fig. 15	5
1 6-inch gun-seat facing machine } Figs. 16 and 17	3
1 4.7-inch gun-seat facing machine } Figs. 16 and 17	3
1 12-pounder facing machine } Figs. 16 and 17	1
1 boring machine for protective decks up to 1½ inches in diameter	2
5 boring machines for armor backing and shells up to 4 inches in diameter.	
2 shaping machines, each	1
2 band saws for metal, each	1
2 circular saws, each	1½
4 drilling machines, each	½
2 emery grinders, each	2
4 grindstones, each	1
1 grinding machine for armor plates	1
Rotary grinding wheel driven from motor by belt and held to armor by hand.	

In Machine Shed.

	Motors—H.P.
6 plate-planing machines, to take plate up to 38 feet by 2 inches thick, each	10
1 large plate-bending rolls, 30 feet long, to take up to 2-inch plate	45
1 smaller plate-bending rolls, 20 feet 6 inches long, to take up to 1½-inch plate	30
1 smaller plate-bending rolls, 14 feet 6 inches long, to take up to 1-inch plate	10
1 large mangle rolls, to take plates up to 6 feet wide	20
1 small mangle rolls, to take plates up to 5 feet wide	5
3 small bending rolls, each	5
35 punching and shearing machines, to punch up to 1½-inch holes in 1½ inch plates, each	5
1 punching and shearing machine, to punch up to 2-inch holes in 2-inch plates	20
7 bar-bending machines, to bend up to 7-inch by 4½ inch angles, each	5
2 hydraulic plate-benders, to bend plates up to 32 inches long by ⅞-inch thick.	
1 double-headed scarfing machine for overlaps of ship plates	5
1 hydraulic channel cutter.	
9 drilling machines, each	3
8 countersinking machines, each	3
1 double-headed screwing machine, 1 six-spindle nut shaping machine } with shaft	5
1 double-geared lathe.	
1 band saw for metal	2
1 circular saw for metal, 6 grindstones, 1 pair of emery wheels, 4 blast fans for smith fires } with shaft	10
11 hydraulic cranes.	
1 10-cwt. hydraulic ash hoist at main boilers.	
1 hydraulic pumping engine with double cylinders, 12 inches by 24 inches, and accumulator; working pressure 1,650 pounds per square inch.	

	Motors—H. P.
1 pneumatic power hammer, 1 cwt.	5
1 5-cwt. steam hammer.	
1 rumbler for cleaning old service bolts.	
1 coke-crushing machine	1½

IN YARD.

	Motors—H.P.
4 cantilever cranes (Figs. 13 to 14) each	85
2 over shipbuilding berths, 190-foot span.	
1 in plate yard, 318-foot span.	
1 in timber yard, 318-foot span.	

IN SMITHS' SHOP.

	Motors—H.P.
1 5-ton steam hammer.	
1 1-ton steam hammer.	
3 10-cwt. steam hammers.	
1 8-cwt. steam hammer.	
4 5-cwt. steam hammers.	
5 drilling machines.	
1 grindstone.	
1 blast fan	40
76 fires and furnaces.	
Heaviest forgings—Rudders up to 17 tons.	
Stern frames up to 14 tons.	

IN PLUMBERS' SHOP.

	Motors—H.P.
6 drilling machines	10 horsepower motor and shaft.
5 pipe-screwing machines to screw pipes up to 4 inches in diameter	
1 pipe-cutting machine to cut pipes up to 12 inches in diameter	
1 band saw for iron	
2 punching and shearing machines	
2 heating and shearing machines, 3-foot gap	
1 sheet-iron rolls to take plates up to 5 feet 6 inches wide	
1 tinsmiths' rolls to take plates up to 3 feet wide	
1 tin-folding machine	
1 tilt hammer	
2 blowing fans, each	5
1 boiler and furnace for lead.	
1 hydraulic boiler tester.	

BOILERS, WINCHES, ETC.

	Motors—H.P.
6 patent flange flues main boilers, 28 feet by 8 feet in diameter, 100 pounds working pressure.	
1 cylindrical, with Galloway's patent flues, 30 feet by 8 feet, for saw mill.	
1 four-furnace marine boiler, 16 feet by 12 feet in diameter, for smithy.	

Motors—H. P.

3 donkey boilers.
6 combined winches and boilers.
4 steam locomotive traveling cranes.
4 steam winches.

11 electric winches.... { 2, each..... 25
4, each..... 8
1..... 5
4, each..... 20

3 donkey feed pumps.
1 double-acting salt-water test pump for testing ships' compartments.
2 portable centrifugal pumps, 6,000 gallons per hour, each..... 3
1 Merryweather fire engine.
1 portable fire engine for attachment to locomotive cranes.

In Joiners' Shop.

Motors—H.P.

1 molding machine..... 10
1 molding machine..... 5
1 circular saw..... 10
2 circular saws, each..... 5
1 sand-papering machine..... 10
1 cross-cut saw..... 3
4 turning lathes, with shaft..... 5
1 pneumatic installation for removing refuse, sawdust, &c., from machines to boiler stokehole, two fans for above..... 2 of 20

3 circular saws.....
5 emery grinding machines.....
3 spindle and hole cutting machines..... } with shafting..... 30
2 band saws.....
1 grating machine.....
9 doweling, mortising, dovetailing, &c., machines...

In Saw Mill.

6 circular saws.
4 band and frame saws.
2 saw-sharpening machines.
1 saw-setting machine.
2 traveling benches.
1 boring machine.
1 planing machine.
1 emery grinder.
1 blast fan for taking sawdust to boiler stokehold.
1 double compound tandem engine.

All the machines in saw mills driven by above engine.

IN BLOCK AND SPAR SHED.

	Motors—H.P.
2 circular saws, each	10
1 band saw, 2 turning lathes, 3 boring, doweling, &c., machines, 1 grindstone — with shaft	5
1 steam drying stove with two fans	20

APPENDIX II.

THE DESCRIPTION OF 100-TON DERRICK CRANE, FIG. 22.

This crane, constructed by the Duisberger Company, late Bechem and Keetman, of Duisburg, for Messrs. Blohm and Voss' Works, Hamburg, was designed to deal with loads of 100 tons, but in order to obtain economical working for smaller loads, the crane has been fitted with two separating hoisting machines and rope tackles for maximum loads of 100 and 30 tons respectively. Each hoisting gear is further constructed for two load speeds, as the following data show:

Large Hoisting Gear.

Loads up to 50 tons, lifted at 2.6 meters (8½ feet) per minute.
Loads from 50 to 100 tons, lifted at 1.3 meters (4¼ feet) per minute.

Small Hoisting Gear.

Loads up to 10 tons, lifted at 12 meters (39 feet) per minute.
Loads from 10 to 30 tons, lifted at 4 meters (13 feet) per minute.

The two hoisting gears are driven by a two-cylinder engine with cylinders 9.5 inches in diameter and 17.7 inches stroke. The speeds above mentioned correspond to 180 revolutions of the engine. For the trials, maximum loads of 150 and 75 tons respectively were applied. In order to secure the highest efficiency

for the hoisting machines worm gearing has altogether been dispensed with; of bevel wheels a limited use has been made, and the main work is done by high-speed spurwheels with cut teeth. The steel-rope drums and sheaves are of exceptionally large diameters. Each single rope, of both tackle systems, has a guaranteed breaking strength of 100 tons, and the load is in the large gear held by eight, and in the small gear by four, such ropes. The large gear comprises two winding drums, on which two ropes are wound simultaneously; the rope strains are thus equalized. The two hooks turn on glass-hard steel balls, and two joints further permit of their being moved in any direction. As Fig. 22 shows, the jib is not fixed, but its range can be varied within the limits shown. It should be noticed that the small ropes may be loaded with the full 30 tons, and the 45 tons of the trials at the maximum range, whilst the loads of 100 and 150 tons are the maximum for a range limited to 20 meters. As the center of the moving jib is only 2.5 meters from the quay edge, the useful radius of the crane is $32.5 - 2.5 = 30$ meters (98 feet). At *a* the upper part of the jib turns about a horizontal pin, and the whole jib turns horizontally about *b* and *c*. These pivots are borne by a tripod structure. The power for both movements is derived from a second two-cylinder engine, 8.3 inches in diameter, 11.8 inches stroke, which is placed in the plane *x y*, and the jib inclination is varied with the aid of two screw spindles of Siemens-Martin steel which have their bearings in the tie *d* of the upper pin *b*. The pitch of the screws and the gearing prevent any unintentional sinking of the jib; an automatic brake has further been added lest the jib should yield to concussion. The horizontal stresses of the jib are taken up by the two pins on the tripod structure. The transference of the vertical stresses was a more difficult problem. The frequently applied support of the jib by rollers or balls of steel was inadvisable in consideration of the large forces, and the relatively small base whose diameter is 4.5 meters (16 feet). A circular path has been adopted which recalls the construction of the guides of a planing bed. The path base is made of steel, and its circumference is fitted with exchangeable steel bolts, with which the toothed wheels of the

two revolving gears engage. These parts are made of great strength on account of the huge masses to be moved and of the wind pressures. When the engine runs at 180 revolutions the jib turns through 30 meters (almost 100 feet) per minute, measured on the small hook with maximum radius. The steam engine does not need a boiler of its own, as the boilers of the wharf are close by. The main steam pipe is common to both the engines, and it is carried through a stuffing box into the geometrical axis of the jib, where it is well insulated. The one machinist who attends to the crane has his stand in the front part of the jib, at a height of about 23 feet above the flooring. From his stand he can follow the motions of the hooks, and attend to all his levers, which are duly marked, without changing his position. The engines, gears, and attendant's stand are all in an iron cab, which is fitted with windows. The tripod structure forms, with its box connections, placed under the floor, an exceedingly strong and rigid system, and the loads are well distributed. The central foundation block, under the jib table, is exposed to vertical pressures only; the two others receive either vertical pressures or act as counterweights for the load.

ELECTRICITY AT THE NEW YORK NAVY YARD.

A DESCRIPTION OF THE NEW POLYPHASE POWER PLANT.

By F. N. Kollock, Jr.

The new power plant of the Bureau of Steam Engineering at the New York Navy Yard is a very striking example of recent advances in electrical power distribution, embodying, as it does, the most advanced practice in alternating-current working.

Immediately after the disastrous fire at the navy yard, in the spring of 1899, plans were made to rebuild on a larger scale the various steam-engineering shops that had been destroyed, and it was decided to install a thoroughly up-to-date electrical plant for the distribution of power for use therein.

A careful comparison was made between alternating and direct-current systems as to their relative merits, and a decision was finally made in favor of the former. In making this decision the naval authorities were largely influenced by two facts—the greater flexibility of the alternating-current system, and the small amount of attention required by alternating-current polyphase motors. It is very possible that in the not far distant future additional shops will be erected in the yard in which power will be required; these shops may or may not be built near the power house. With the alternating-current system installed the static transformer, a very efficient piece of apparatus, provides a means whereby the generator voltage may be raised and the necessary power transmitted to any required distance without appreciable loss, and without the expenditure of large sums for the heavy copper conductors demanded by low-voltage direct currents.

At the end of the transmission line step-down transformers are employed to reduce the voltage to the same value as that of the generators, and thus the motors there operated may be of the

same standard characteristics as those installed in the shops near the power house.

The second consideration, that relating to the handling of the individual motors, is of serious moment, as those who have had experience with sparking commutators, and the many other ills to which the D. C. motor is heir, can readily testify.

In the modern polyphase motor there is presented the simplest piece of rotating electrical machinery now on the market, and it is consequently especially adapted for use in industrial plants where the best of care is not always given to intricate mechanism, and where the motor is necessarily placed in charge of workmen inexperienced in electrical matters.

These motors are so designed and constructed that they require a minimum amount of attention, and in fact all that is necessary is to start and stop them, as occasion demands, by throwing a simple switch, and to make a weekly inspection to see that the oil pockets are kept filled to properly lubricate the bearings; further, they will stand almost any amount of abuse in the way of overloads, etc., without being damaged.

Another feature of this type of motor is that all of the machines can be controlled by starting or stopping the main generators, and without any attention being given to the individual motors. This makes a shut down for the noon hour a very simple matter, and renders unnecessary the amount of labor involved in the use of any other form of power.

Detail specifications were drawn by the Bureau of Steam Engineering, and on June 21, 1899, the Paymaster General advertised, inviting proposals for the complete equipment of engines, boilers, generators, motors, etc.

The contract for the entire plant was finally secured by the Westinghouse Electric and Manufacturing Company, delivery of the apparatus installed being guaranteed in one year from the signing of the contract, October 18, 1899.

Owing to delays in the construction of the power house, the plant was not completed as soon as had been expected, and the trial run of thirty days is only just about to be made.

Before taking up the electrical features of this installation, the

discussion of which is the object of this paper, it may be of interest to give a brief account of the new shops, the power house and its mechanical equipment.

The new steam-engineering shops consist of three buildings: the machine shop, the boiler shop and the erecting shop, forming three sides of a rectangle, with the machine shop as the longer side. The new buildings are of fireproof construction throughout, as is the power house, as described below.

The machine shop, which is entirely new, is 350 feet long by 130 feet wide, and is divided into three aisles by the columns supporting the roof, the central aisle being 70 feet wide and the outside aisles each 30 feet wide. The double-pitched roof over the main aisle is built entirely of steel framework and glass, as are also the sides of the clerestory. This construction, together with the numerous skylights in the single-pitched slate roofs of the side aisles, and the many windows, produce an unusually well lighted interior. The erecting shop, also entirely new, is 252 feet long by 130 feet wide, and is of a design similar to the machine shop described above. The boiler shop is 300 feet long by 96 feet wide, and is only partly of new construction.

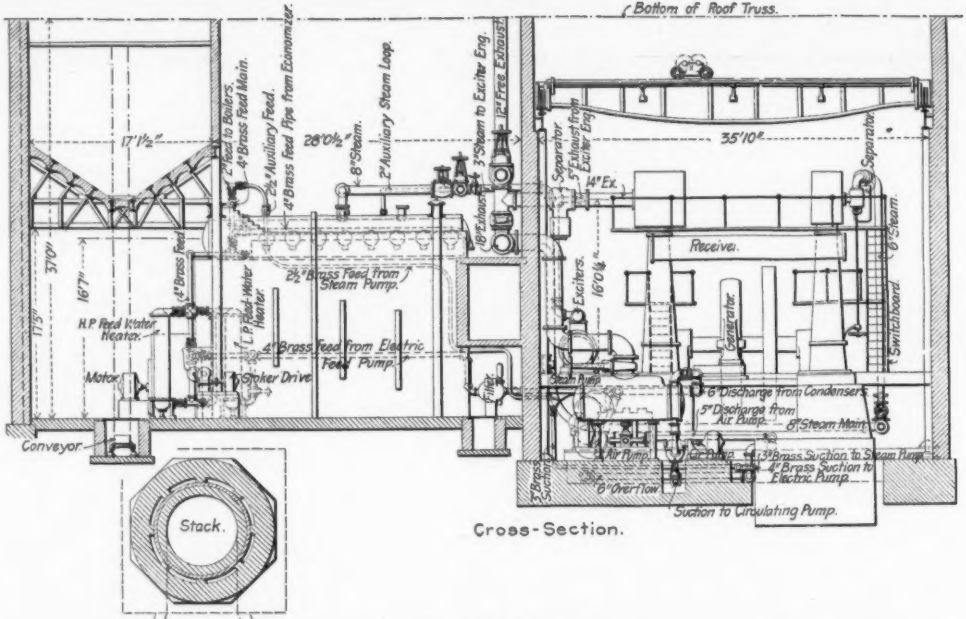
The flooring of all of the buildings is of cement, and in fact, every known means, such as wire mesh partitions, iron shelving, metal doors, etc., have been employed to render a repetition of the extensive fire impossible.

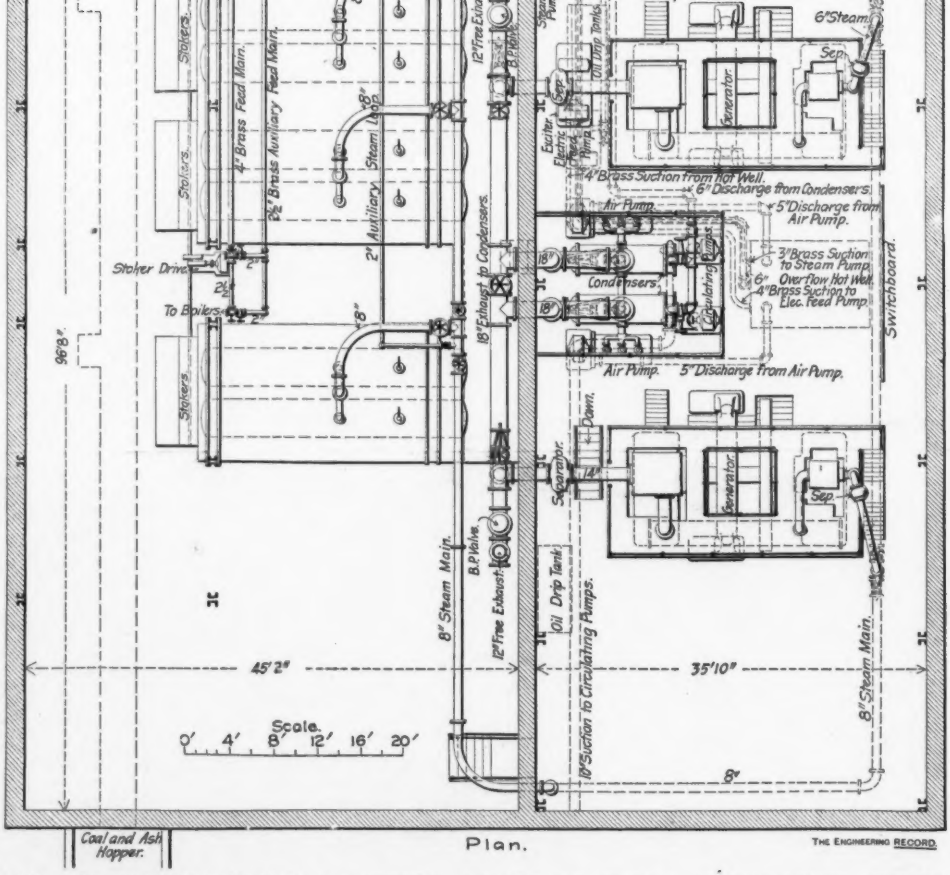
The equipment of the shops is very complete, and the various tool builders, realizing that their machines would be in competition with those of almost every other manufacturer, have used their best endeavors to make the character of their installation of the very highest.

The power used throughout the steam-engineering shops, with the exception of that for the cranes, is furnished by alternating-current motors, directly connected to the larger machine tools, and belted to countershafting for driving the smaller tools.

The various machinery used in the foundry, blacksmith shop and pattern shop (which buildings were not destroyed and have not been rebuilt) is also driven by alternating-current motors.

The crane equipment consists of three cranes in the machine


Bottom of Roof Truss.
17'1½"
37'0"
16'7"
17'5"
28'0½"
35'10"
Conveyor.
Stack.
Receiver.
Exciters.
Generator.
Switchboard.
Separator
Steam Pump
Air Pump
Filter
Cross-Section.
Discharge Chamber.
Economizer.
Fan.
Motor
Stokers.
Generator.
Sep.
Steam Pump
Filter
4" Brass Feed Pipe.



PLAN AND CROSS-SECTION OF POWER HOUSE OF STEAM ENGINEERING SHOPS, NEW YORK NAVY YARD.

(Cuts loaned by "Engineering Record.")

shop and three in the erecting shop. In the main aisle of the machine shop is a 25-ton crane, built by the Morgan Engineering Company, and two 10-ton cranes built by the Pawling & Harnischfeger Company, the larger crane running on a track above that of the other two. In the erecting shop the crane equipment is similar, the larger one, however, being of 40 tons capacity, and built by the Niles Tool Works Company.

All of these cranes are operated by direct-current motors, the power for which is obtained temporarily from direct-current generators; the plan being to ultimately install rotary converters for such service, these machines to be operated from the main alternating-current generating plant.

The power house was designed by the Bureau of Yards and Docks, and built under the supervision of the navy yard authorities. The building is 100 feet long by 86 feet wide, built of brick with granite trimmings, and is located at a distance of about 60 feet from the machine shop, boiler shop and erecting shop.

The original idea was to place the power house within the rectangle made by the shops as above described, but in order to afford the shops as much light as possible, and also to minimize the fire risk, the present location was decided upon. The foundations for the building and for the engines, generators and boilers installed therein are of concrete built on piles.

The engine room, separated from the boiler room by a brick partition, is 97 feet long by 36 feet wide, and is arranged to accommodate four generator outfits, the necessary exciter and switchboard equipment, the condensing apparatus, and the boiler feed pump, the air pump and the circulating pumps, which latter are motor driven.

The engine-room floor is 4 feet above the ground level, and an 8-foot basement is provided for the reception of the condensing apparatus and all piping and wiring. The boiler room, 96 feet 8 inches long by 45 feet 2 inches wide, is arranged for three boilers of 300 horsepower each, and space is provided for the installation of one 100 horsepower boiler with independent steam-driven feed pump, and for the coal and ash-handling apparatus,

the mechanical draft and the Roney mechanical stoker, all of which machinery is also driven by alternating-current motors.

All of the apparatus in the power house, with the exception of the electrical equipment, was installed under the supervision of Westinghouse, Church, Kerr & Company, the Westinghouse Electric and Manufacturing Company (the main contractor) furnishing and installing the entire electrical equipment, including the generators, exciters, switchboard and auxiliary motors.

Three engine-type generating units, as called for in the contract, have been installed. The engines are of the vertical cross-compound type, and were manufactured by McIntosh, Seymour & Co. The high-pressure cylinders are 16 inches and the low-pressure cylinders 34 inches in diameter, the stroke being 36 inches. The engines operate at a speed of 136 revolutions per minute, and are rated at 630 horsepower each, at an initial steam pressure of 160 pounds and a vacuum of 26 inches. Each engine is equipped with an electric governor, by means of which the speed can be varied 3 per cent. in either direction from the normal while the engines are in operation. The motor actuating this governor is situated on the engine fly wheel. Aside from this electrical governor, a centrifugal governor is supplied to closely regulate the speed of the engine, which feature is so vital to the successful operation of alternating-current generators in multiple. A Westinghouse vertical, cross-compound, high-speed engine is provided, to which one of the two exciters furnished is directly connected. The high and low-pressure cylinders are 8 inches and 13 inches in diameter, respectively, and the stroke is 8 inches. The engine operates at a speed of 375 revolutions per minute and is rated at 60 horsepower at a steam pressure of 160 pounds and a 26-inch vacuum. The steam piping is arranged so that this engine, or any one of the three main engines, can also be run independently non-condensing. The two circulating pumps, both of which are motor driven, are of the centrifugal type and were manufactured by R. D. Wood & Co.

The two air pumps are of the Blake, vertical, triplex, double-action, valveless type, also motor driven, and operate at a speed of approximately 55 revolutions per minute. The feed pump is

of the Blake pattern, and is connected to its driving motor through a set of double reduction gears, being designed to run at a speed of 32 revolutions per minute; there is also a Blake single-acting plunger pump installed as an auxiliary feed pump.

The engine room is completely equipped with Wheeler surface condensers, Edmiston oil filters, and steam separators of the Cochran type; the Holly system of drainage is used throughout. A manually-operated traveling crane of 15 tons capacity is also provided for handling the various machine parts.

The boiler equipment consists, as above set forth, of three units, each of 300 horsepower capacity, two being connected in one battery and one being set singly. The boilers are of the water-tubular type and of Babcock and Wilcox design and construction. The system of rating used is that 1 horsepower equals the evaporation of 30 pounds of water per hour from 100 degrees Fahrenheit at 70 pounds pressure. The four-inch tubes of which the boilers are constructed are 18 feet long, 192 tubes being used in each unit arranged in 16 sections, 12 to a section. Each boiler has a heating surface of 4,000 square feet and a grate surface of 80 square feet. The steam drums, 42 inches in diameter, are built of plates of open-hearth, forged steel and the boilers as a whole were designed to carry a working pressure of 200 pounds.

The 100-horsepower independent boiler, as referred to above, will be used, when installed, for testing purposes, and will be designed to carry a maximum pressure of 500 pounds.

A complete equipment of Roney mechanical stokers is provided, and arrangement is made so that the rate of feed can be varied at will without interrupting the rotation of the stoker shaft. The stokers are all driven by a single motor. The guarantee covering the boilers and stokers specifies that, when operating at rated capacity, they will evaporate 11.3 pounds of water from a temperature of 290 degrees Fahrenheit, into steam, at 160 pounds pressure per square inch, per 1 pound of Pocahontas coal.

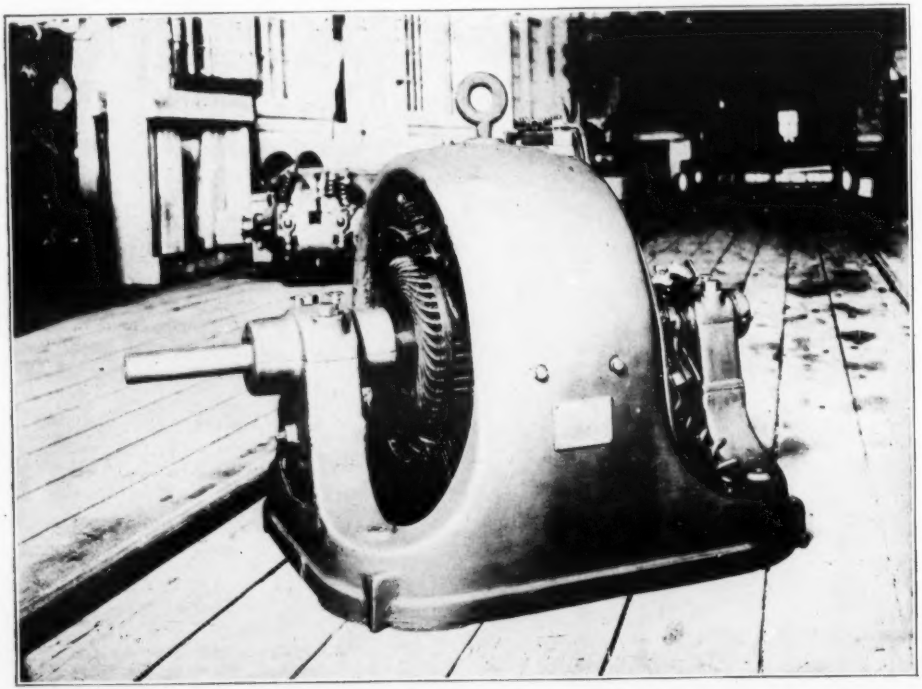
The coal and ash-handling machinery consists of a conveyor of the steel-cable and bucket type, and was built by the Steel Cable Engineering Company. The coal is received in a hopper

placed beneath the railroad siding, which runs close to the power house, and, after passing through a grating with 3½-inch interstices to break the larger lumps, is carried in the conveyor buckets to the overhead bins in the boiler house. From here it is fed to the grates by means of wrought-iron dust-proof chutes, and the ashes are received again in the conveyor buckets running in a covered trench in front of the boilers and carried to an outside, overhead hopper. The conveyor system has a capacity of 30 tons of coal per hour and is driven, through reduction gearing, by an alternating-current motor.

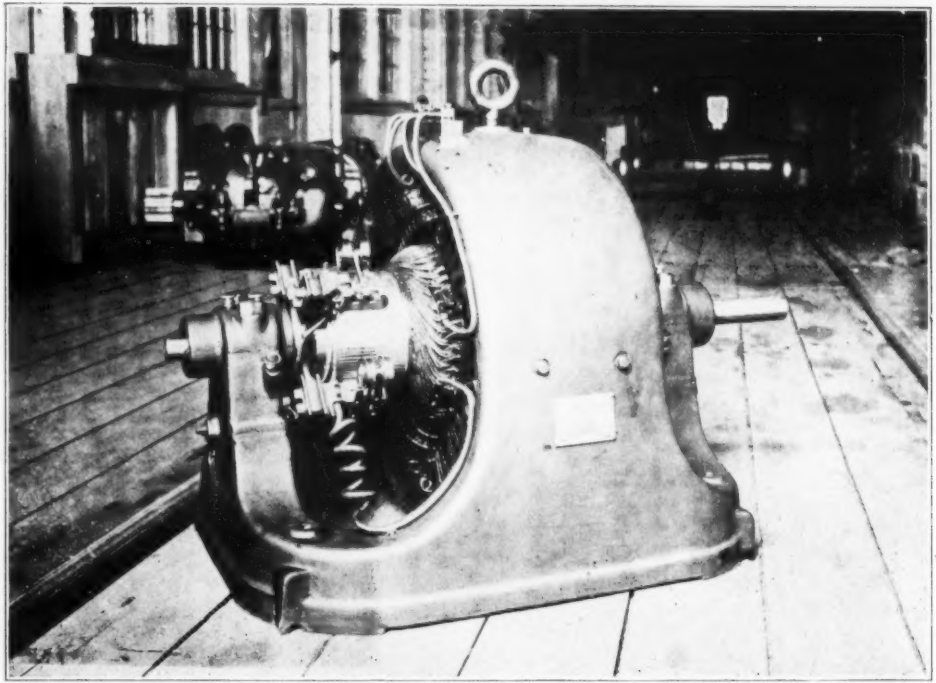
A Westinghouse improved, high-pressure, circulating-type economizer is provided for heating the feed water in its passage from the hot well in the engine room and the Wheeler, vertical feed-water heaters to the boilers. The economizer is capable of heating the required body of water for two boilers from a temperature of 110 degrees Fahrenheit to a temperature of 200 degrees Fahrenheit, provided all the furnace gases from the two boilers pass through the economizer and the boilers are being operated at or above rating. Should the feed water reach the economizer at 190 degrees Fahrenheit under the above conditions, it is capable of raising its temperature 65 degrees Fahrenheit. Owing to the mechanical resistance imposed by the economizer to the passage of the gases, as well as the insufficiency of the draft which would be produced by the 150-foot stack with gases at the low temperature at which they would leave the economizer, a motor-driven blower has been installed for producing a forced draft. The blower fan is 92 inches in diameter and 46½ inches in width.

After careful consideration as to the electrical characteristics of the generating units, it was finally decided to install a system having low alternations and operating at a low voltage. The low speed of the engines, 136 revolutions per minute, as above given, required fewer poles with generators so designed and, therefore, the adoption of such a system meant a reduction in the diameter and size and, consequently, in the cost thereof.

The probable use of rotary converters for furnishing power to the direct-current crane motors was also taken into consideration



WESTINGHOUSE 20-KILOWATT MULTIPOLAR EXCITER, MOTOR DRIVEN. REAR VIEW.



WESTINGHOUSE 20-KILOWATT MULTIPOLAR EXCITER, MOTOR DRIVEN. FRONT VIEW.

and, inasmuch as there is a well known objection on the part of the majority of the builders of such apparatus to high alternation rotary converters, it was decided that, all things considered, it would be best to install a 3,000 alternation system.

In deciding the question of the voltage to be employed, the object was, of course, to have as low a voltage as possible, to lessen the possible troubles due to breakdowns of insulation, and still have it high enough to reduce line losses to a minimum and cut down the necessary amounts of copper in electrical apparatus and line wires. The proximity of the power house to the shops in which the power was to be utilized made a high voltage unnecessary, and this fact, together with the increased safety to attendants in the power house and the workmen, unfamiliar with electrical machinery, in the various shops, convinced the naval authorities that an electro-motive force of 220 volts at the generators would best meet their requirements. It was further decided that a two-phase system would be best under existing conditions.

The three generators therefor, as called for by the specifications and furnished under the contract, are designed to operate at 25 periods per second or 3,000 alternations per minute, two-phase, and at an electro-motive force of 220 volts; the speed being 136 revolutions per minute, the number of poles is fixed at 22. The generators are of the revolving-armature type, the revolving element being pressed on the engine shaft at 75 tons pressure and secured by means of a 3-inch feather key.

The armature is built up of a laminated steel punching of a high magnetic quality, pressed on the periphery of a cast-iron spider; the punchings being secured in place by being dovetailed carefully into slots in the spider rim. The laminated core thus built up is held firmly in place and prevented from moving laterally by steel end plates fastened by steel rings sprung into slots machined into the edges of the spider. By means of brass ventilating discs encircling the spider and placed between the punchings, the laminated core is divided at right angles to the shaft into a number of sections, each about 3 inches wide, between which a forced circulation of air is set up, thus securing

thorough ventilation of both the core and the armature winding and ensuring a low operating temperature.

The spider itself is of massive design, thus giving a large fly-wheel effect, and is constructed in a way similar to that used in building ordinary engine fly wheels, *i. e.*, the rim on which the laminated core is built is supported from the hub by a number, six in the present case, of webbed spokes. The advantage of this construction is readily seen, in that a further forced circulation is set up, tending to reduce the operating temperature.

The armature winding consists of copper bars carefully insulated with paper, tape and varnish before being placed in position. The bars are slipped into the armature slots from one side, and are held in position by the overhanging tips of the armature teeth. Connection to the bars is made by means of copper connectors bolted and soldered on at the ends after the bars are in place.

The design of the armature winding determines to a large extent the characteristics of the generator in respect to regulation, and the good regulation of these machines is largely due to the great number of slots per phase per pole. By such construction the self induction of the armature winding is decreased and it is possible to increase the generator voltage, even when operating on inductive loads.

The collector is built of brass rings, carefully insulated from each other, of special quality adapted for this service. The rings are placed on an insulated iron bushing and the whole collector is placed on the engine shaft, entirely independent of the armature. It is forced into position by means of a hydraulic press, at five tons pressure, and is secured to the shaft by a $1\frac{1}{2}$-inch feather key. The diameter of the armature is 105 inches and the weight 18,000 pounds. The engine shaft is adapted to carry 7,500 pounds additional, this being the value of the unbalanced magnetic pull of the field coils if for any reason the armature is displaced $\frac{1}{32}$ of an inch from the geometric field center. The total weight of the generator is 46,000 pounds.

The brush-holder stand is built in the form of an inverted U, and is supported over the engine shaft by means of two cast-iron

brackets, fastened to the side of the engine foundations by anchor bolts. This stand carried the four brush-holder arms, on which are placed the brush holders. The brushes are of copper, and are of sufficient size to carry the current given by the machine when operating at heavy overloads without dangerous heating.

The stationary fields of these generators are divided in a horizontal plane and are supported over the armature by lugs cast on the sides of the lower half of the yokes. By this means a considerable portion of the field frames and armatures have been placed below the engine-room floor in specially prepared flywheel pits and the overhead space in the station economized. The side-supporting lugs are placed on massive cast-iron bed plates, which are secured by anchor bolts to the masonry foundations. Provisions are made so that the fields can be moved on these bed plates in a direction parallel to the shaft, and the armature and field winding thus are completely exposed and made easily accessible for making necessary repairs. Further, if it is necessary to remove the engine shaft and the armature for any reason, the top half of the field may be readily lifted by means of the traveling crane.

The field yokes are made of the best quality of cast iron, sound and free from blow holes, and the laminated steel pole pieces are cast into the yoke. This construction, although very expensive, is more than justified by the results obtained. The magnetic circuit is perfected and, on the whole, the general performance of the machine is far better than if the pole pieces were bolted in place or secured by any other means. The advantage of laminated pole pieces in reducing the losses due to Foucault currents needs no detailed explanation.

The field coils are machine-wound on wooden forms and are thoroughly insulated before being placed on the machine. They are then so arranged that a good air circulation may be maintained between them, and their temperature kept very low.

The insulation of the generators is designed to stand a puncture test of 2,000 volts alternating electro-motive force for the armature and 1,000 volts alternating electro-motive force for the field coils. The fields are separately excited at a pressure of 100

volts, and each machine requires, at that pressure, a current of 60 ampères when delivering its full rated load at 100 per cent. power factor. Fifteen per cent. greater current is required when the machines are carrying full load at 90 per cent. power factor.

The makers have guaranteed for these generators an efficiency at full non-inductive load of 94½ per cent.; at ¾ load, an efficiency of 93 per cent.; at ½ load, an efficiency of 90½ per cent., and at ¼ load, an efficiency of 84 per cent., the figures being based on measurements of the copper and iron losses separately determined and exclusive of friction.

The guaranteed regulation is a rise in voltage of 6 per cent., full non-inductive load being thrown off, constant speed and constant separate excitation obtaining. As above set forth, every possible precaution has been taken to keep the operating temperature of the machine as low as possible, and it is guaranteed that they will operate continuously under full load, 90 to 100 per cent. power factor, with a resulting rise in temperature in no part to exceed 40 degrees centigrade. At 25 per cent. overload continuously, 90 to 100 per cent power factor, the rise will not exceed 50 degrees centigrade, and at 50 per cent. overload for one hour, with the same power factor, the rise will not exceed 60 degrees centigrade.

Although the official test of the plant has not, as yet, been made, the indications are that these limits are very high and that the machines will run at much lower temperatures under these conditions.

For the excitation of the three alternating-current generators, two direct current outfits are provided, an engine-driven exciter and a motor-driven exciter. Either outfit is of sufficient capacity to excite two generators under any conditions of load, and, as the present requirements for power can easily be met by two machines, the third being kept in reserve, it will only be necessary to operate one of the exciters at a time. The engine-driven exciter will be used when the alternating-current machines are being started, and, after their voltage has been brought up to normal, the exciter driven by the alternating-current motor will be put in service and the engine-type outfit shut down.

The engine-type exciter was designed for an output of 25 kilowatts, 200 ampères at 125 volts, and to operate at a speed of 375 revolutions per minute, as above given for the Westinghouse compound engine by which it is driven. The revolving element of this machine consists of a cast-iron ventilated bushing on which is built the armature core of the slotted-drum type and the commutator, the latter being properly insulated therefrom by means of layers of built-up mica. The iron bushing is pressed on the engine shaft and is held in place by a 1-inch steel feather key.

The design and construction of the core is similar to that of the alternating-current generators, with the exception that the tips of the armature teeth do not overhang; the same provisions are made for ventilation and for setting up a forced circulation of air. The armature coils are made of copper bars, rectangular in section, which are forged into shape and carefully insulated before being placed in the armature slots; these are held in place by banding around the armature core. The winding is divided into two circuits so arranged that they will not become unbalanced through a displacement of the armature from the geometric center of the field. A displacement of $\frac{1}{32}$ inch is, by reason of this construction, permissible, and there is no resulting injurious sparking at the brushes, no vibration in the armature, and each brush delivers its *pro rata* share of current.

The commutator is built of bars of hard-drawn copper properly insulated from each other by sheets of mica, and the number of bars is such that, with an electro-motive force of 125 volts on the machine terminals, the average difference of potential between adjacent bars does not exceed 5 volts.

The total weight of the revolving element is 900 pounds, and the engine shaft is made sufficiently strong to carry a load of 1,500 pounds additional, which may occur, due to the possible displacement of the armature. Attention has already been called to a similar provision made in the case of the large engine shafts.

The field frame is constructed of the best quality of cast iron, and the pole pieces, six in number, are made of laminated steel. The pole pieces are so designed that they are easily saturated at the tips, thus reducing the distortion due to armature reaction to

a minimum. The field winding is of the ordinary compound form, the series and shunt coils being separated from each other and separately insulated to permit of through ventilation. The six swivel-type brush holders are carried on a ring supported by the yoke. This ring is readily moved and permits of an easy adjustment of the brushes should this be necessary.

The carbon brushes are of such a size that the normal current density therein, when the machine is operating at full load, is approximately 38 ampères per square inch.

The efficiency of the machine is at full load, 89 per cent.; at three-fourths load, 88½ per cent.; one-half load, 87 per cent., and at one-fourth load, 81 per cent. The field windings are so proportioned that the generator will over compound approximately 6 per cent. from no load to full load.

After full-load operation for six hours the rise in temperature of any part, including the commutator, will not exceed 40 degrees centigrade above the surrounding air.

Subsequent to a run of this kind the generator may be operated at 50 per cent. overload for a period of one hour, and the additional rise in temperature will not exceed 10 degrees centigrade. The machine will also carry momentarily an overload of 75 per cent. without injurious heating.

The motor-driven exciter to which reference has already been made is of a similiar construction to the engine-type exciter just described.

The machine has a capacity of 20 kilowatts, or 160 ampères at 125 volts, and operates at a speed of 720 revolutions per minute. The armature punchings and the commutator are, however, pressed directly on the shaft to which they are accurately keyed, and the armature coils are wire-wound. The field is designed with four-pole pieces of the same general construction as above described. This machine is placed on a common cast-iron bed plate with its driving motor, to which it is directly coupled.

The guaranteed efficiency is, at full load, 89 per cent.; at ¾ load, 89 per cent.; at ½ load, 87 per cent., and at ¼ load, 79 per cent., these values being determined, as in the case of the engine-

type exciter, by the separate loss-measurement method described above for the alternating-current generators.

The compound field winding is so designed that the same over-compounding, viz: 6 per cent., will be produced from no load to full load, as is the case of the engine-driven exciter, and the rise in temperature after a six hours' run is the same, viz: 40 degrees centigrade maximum in any part; but for overload runs the limits are somewhat lower, being a maximum total rise of 50 per cent. centigrade, after a one-hour run at 25 per cent. overload made immediately after the full-load run, and a permissible momentary overload of 50 per cent., without injurious heating. The brush holders are supported from a yoke on the bearing housing; four brush holders are supplied, and an area of carbon-contact surface is presented to the commutator sufficient to make the current density in the brushes not exceed 34½ ampères per square inch, the machine carrying its rated load.

A switchboard is installed which embodies in its design controling apparatus and measuring instruments of the most recent and approved type. This switchboard controls the three alternating-current generators, both of the exciters and a total of twelve two-phase feeder circuits, which extend to various parts of the shops, and by means of which power for all of the motors is distributed. The board is 18 feet long by 90 inches high, and consists of nine white Italian-marble panels, highly polished and beveled ½ inch all around, each panel being made up of two slabs, the upper 24 inches by 65 inches and the lower 24 inches by 25 inches. The first panel, counting from the left as one stands facing the board, has mounted upon it three two-pole, single-throw switches used to control three direct-current feeder circuits, all of which are energized from the single set of main-exciter busbars to which both exciters may be connected.

Panel No. 2 controls the two direct-current machines and is equipped with two three-pole single-throw main switches, the third blade being used as an equalizer when the exciters are run in multiple, two direct-current ammeters, two rheostats mounted back of the marble and having the operating hand wheel on the front of the board and a direct-current voltmeter arranged to be

connected to either machine. There is also a full equipment of voltmeter plugs and receptacles and a ground-detector outfit.

Panels Nos. 3, 4 and 5 are arranged each to control one of the 400-kilowatt alternating-current generators, and on each panel is mounted one four-pole single-throw main switch, two alternating-current ammeters, one polyphase indicating wattmeter, and a rheostat face plate mounted back of the panel and furnished with projecting hand wheel. The resistance is of the iron-clad type and is mounted in racks apart from the board.

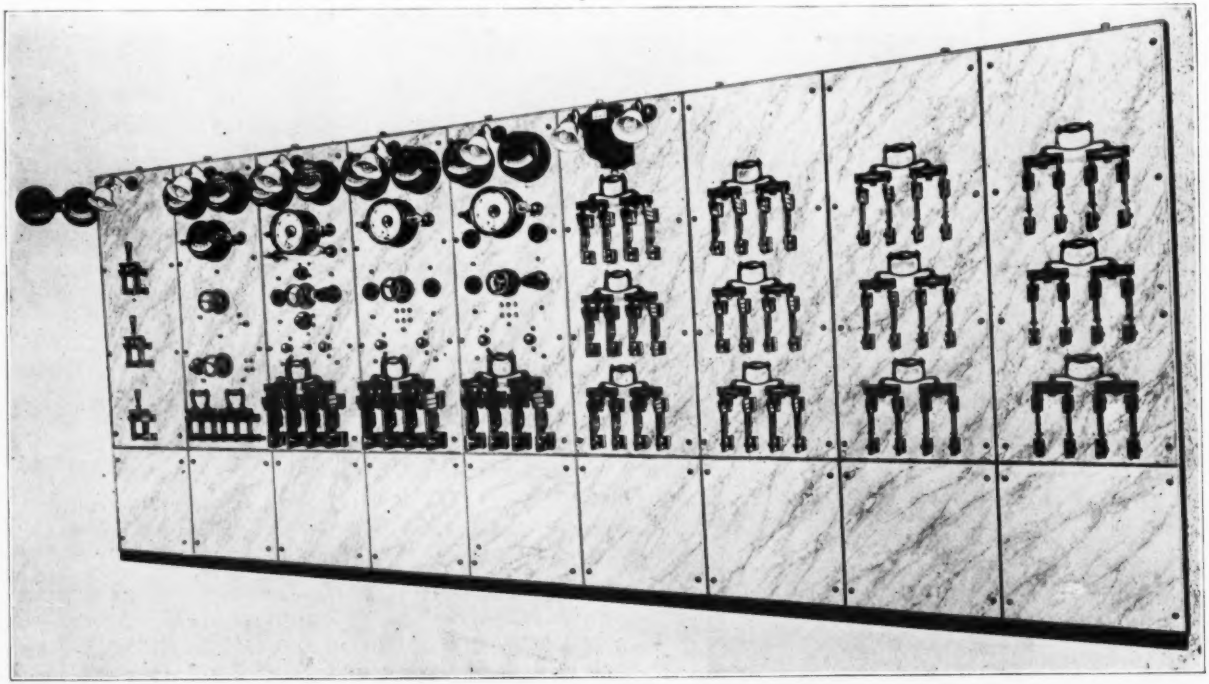
Each panel is also supplied with two plug switches for controlling the generator field circuits, and, like the exciter panel, with voltmeter plugs and receptacles and all necessary ground detector apparatus. Synchronizing devices are also furnished in order to indicate the moment at which the generators may be thrown in multiple.

A single set of two-phase busbars is supplied, to which any or all of the generators may be connected by means of the main four-pole switches, and the various feeder circuits are all connected thereto through the feeder busbars and switches.

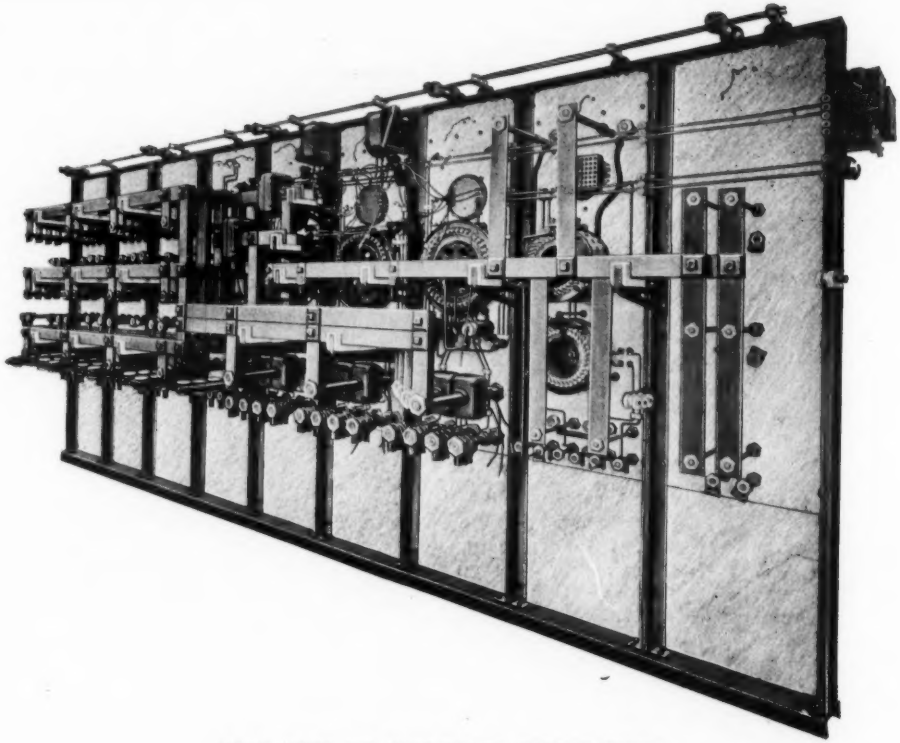
Two alternating-current voltmeters are mounted on a swinging bracket at the left-hand end of the board, one being arranged for connection directly to the alternating-current busbars and the other to any one of the three machines. By this means a comparison can readily be made by the station attendant when manipulating any of the switches between the busbar voltage and the voltage of the generator about to be thrown into synchronism therewith.

The feeder panels Nos. 6, 7, 8 and 9 are duplicates of each other, except that on panel No. 6 a polyphase, integrating wattmeter is mounted, the instrument being so connected as to record the entire output of all of the operating generators.

Each of these panels is equipped with three four-pole single-throw switches, and three sets of two-phase busbars are provided extending across the four panels, all of which are connected to the main generator busbars. This arrangement gives twelve independent two-phase feeder circuits, which, as above stated, furnish power to all of the alternating-current motors installed.



FRONT VIEW OF NINE-PANEL SWITCHBOARD.



REAR VIEW OF NINE-PANEL SWITCHBOARD.

The sub-panels, which extend to the floor of the engine room, support the various fuses mounted in the rear of the board.

Surmounting the board is an ornamental grillwork in which is placed a handsome time piece.

The capacities of the various instruments on the board, both recording and indicating, are such that the generators may operate at 50 per cent. overload, and the switches, of the unit-blade type throughout, are designed to carry the current resulting from this load when at a power factor of 80 per cent., with a temperature rise not to exceed 20 degrees centigrade above the surrounding air. All of the panels are supplied with pilot lamps mounted on ornamental metal brackets.

The wiring diagram shown gives in detail the various connections as above described, and the cuts showing the front and rear views of the board show clearly the detail construction.

It is stated that on this switchboard connections are made to permit of parallel operation of the generators, and it might be well at this time to discuss the various requirements for such parallel operation.

When direct-current generators are run in multiple the only requisite is that the electro-motive forces generated by the machines under consideration shall be the same. In the multiple operation of alternating-current generators not only is this required, but also the most careful design is necessary to insure the generators having the same wave form; and, further, the regulation of the driving engines must be such that at all loads the angular velocity of the revolving element of the generator shall be practically constant. In large engine-type outfits, such as those under discussion, in which the generators have a large number of poles, this latter requirement is of special importance. The total variation in speed during one revolution (that is, the amount which the revolving element forges ahead plus the amount it lags behind the position of uniform rotation) must not exceed $\frac{1}{30}$ of the pitch angle between two adjacent poles; and where the poles are very close together the equivalent per centage of the circumference of the revolving part is very small. In

REAR VIEW OF NINE-PANEL SWITCHBOARD.

the case of these 22-pole machines the maximum permissible variation on either side of uniform rotation is .27 degrees, or .0750 per cent. of the circumference of the armature.

The securing of such uniform speed is accomplished by means of very heavy engine fly wheels having great inertia, which inertia tends to overcome any speed variation due to sudden changes of the load. These changes are apt to be so rapid and of such brief duration that any form of engine governor is entirely inadequate.

Engines which are to be used to drive alternating-current generators, especially those to which the revolving element of the generator is to be rigidly connected, should, however, be equipped with governors of the most approved type for regulating within the ordinary limits; and, further, these governors should be adjustable while the engines are running, in order to facilitate synchronizing the machines.

The motors used to drive the auxiliary apparatus in the power house are all connected directly to the alternating-current feeder panels, and are as follows:

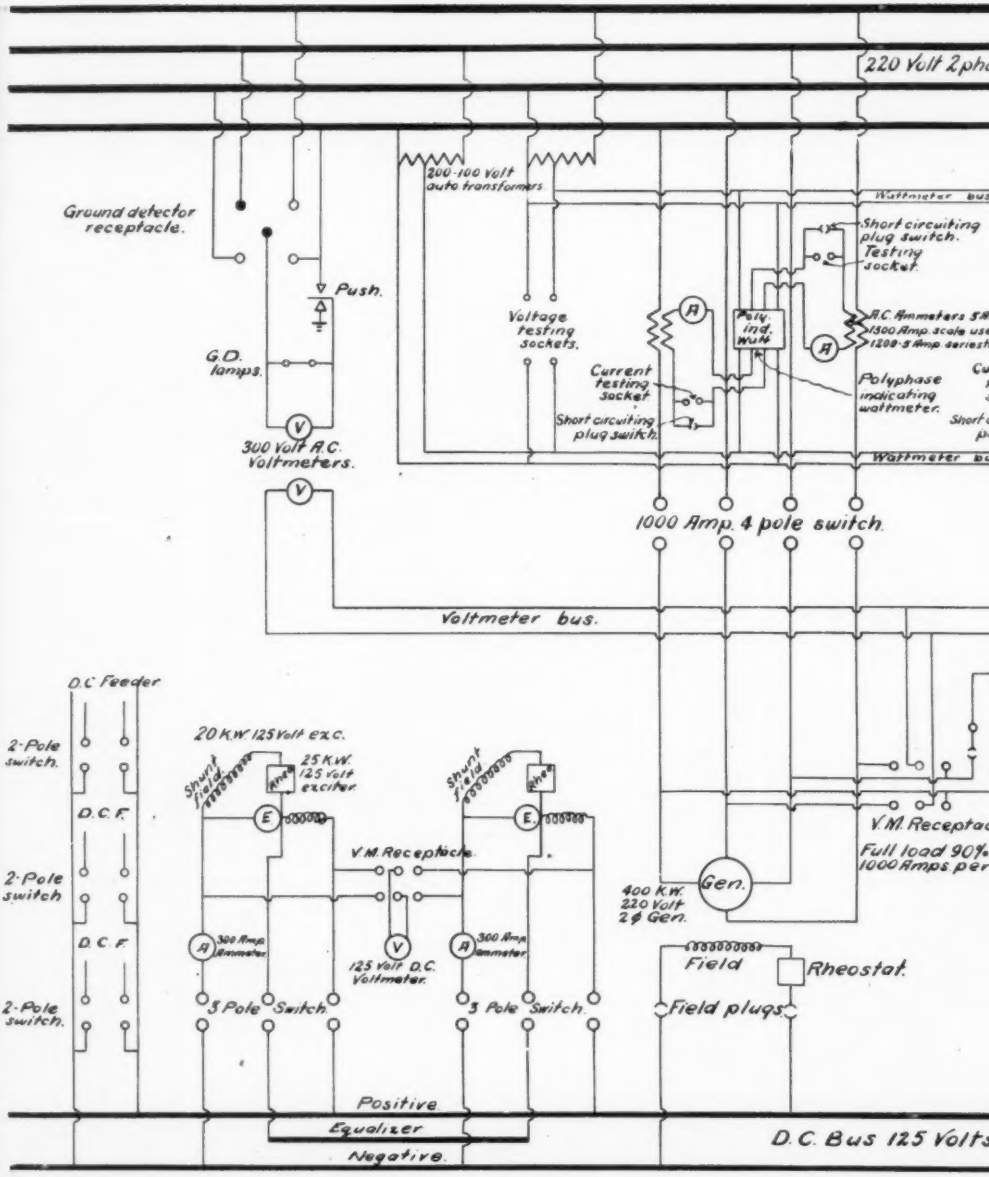
For driving the multipolar exciter a 30-horsepower motor is installed, operating at a speed of 720 revolutions per minute, the speed of the direct-current generator to which it is directly connected.

The air pumps, the circulating pump and one of the feed pumps are driven by motors of 12 horsepower, 10 horsepower and 7½ horsepower capacity, respectively.

The two air-pump motors are wound for a full-load speed of 350 revolutions per minute, and are connected to the pumps by a single reduction gearing at a ratio of approximately 6½ to 1. The motors are mounted on an extension of the pump bed plates.

The motors for driving the two circulating pumps are also mounted in a common cast-iron bed plate with the apparatus to which they are connected, and operate at a speed of 710 revolutions per minute, being connected to the pumps through a single reduction gearing.

The feed-pump motor is arranged to operate at two speeds, 470 revolutions per minute or 235 revolutions per minute, having


220 Volt 2 pha
200-100 Volt auto transformers
Wattmeter bus
Ground detector receptacle.
Push.
Short circuiting plug switch.
Testing socket.
Voltage testing sockets.
Poly. ind. Watt
A.C. Ammeters 5 A
1500 Amp. scale use
1200-5 Amp. series
G.D. lamps.
Current testing socket
Polyphase indicating wattmeter.
Short circuiting plug switch.
300 Volt A.C. Voltmeters.
Wattmeter bus
1000 Amp. 4 pole switch.
Voltmeter bus.
D.C. Feeder
2-Pole switch.
20 K.W. 125 Volt exc.
Shunt field
25 K.W. 125 Volt exciter
D.C.F.
V.M. Receptacle
V.M. Receptac
Full load 90%
1000 Amps. per
2-Pole switch
400 K.W. 220 Volt 2φ Gen.
Gen.
D.C.F.
300 Amp. Ammeter
125 Volt D.C. Voltmeter.
300 Amp. Ammeter
Field
Rheostat.
2-Pole switch.
3 Pole Switch.
3 Pole Switch.
Field plugs
Positive
Equalizer
Negative.
D.C. Bus 125 Volts

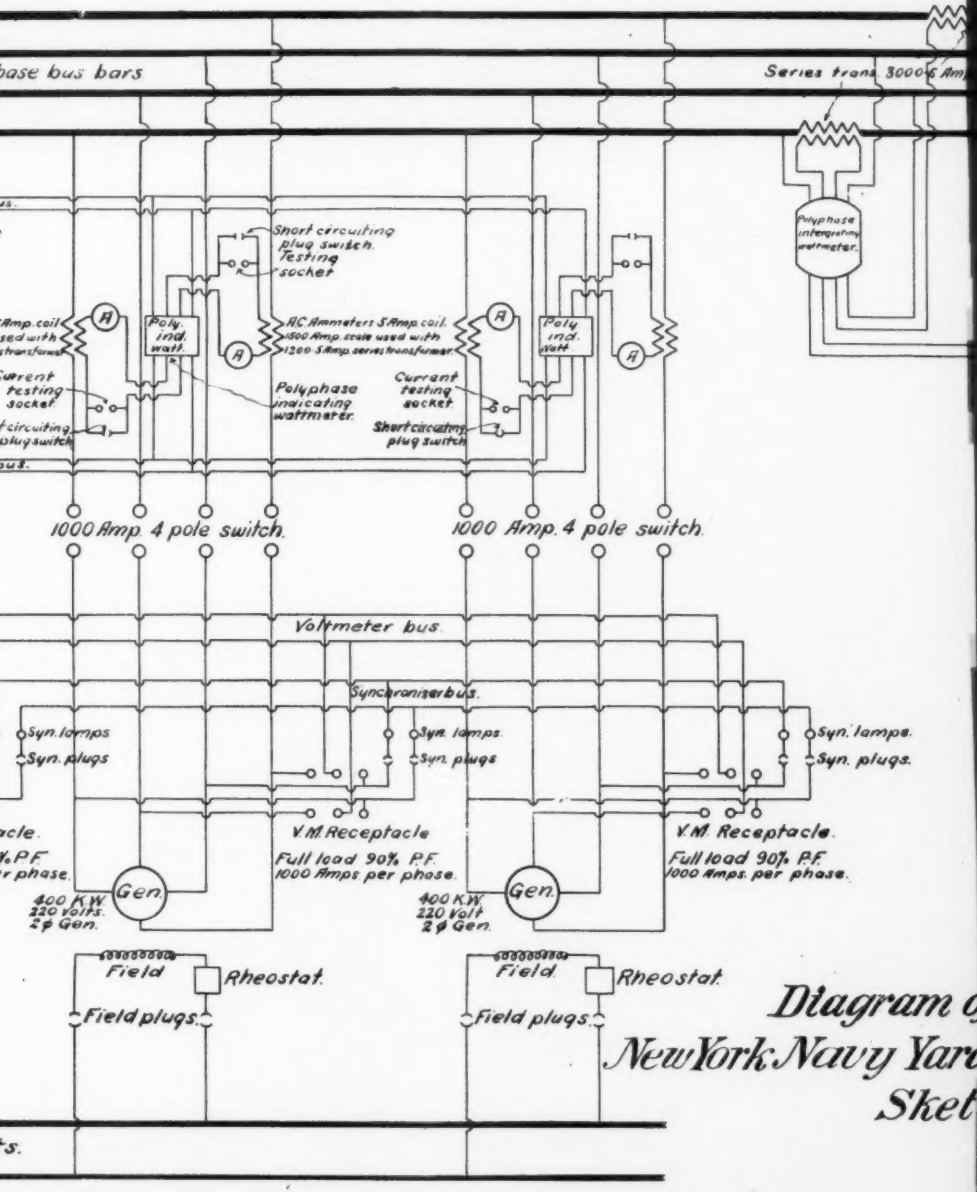


Diagram o

New York Navy Yard

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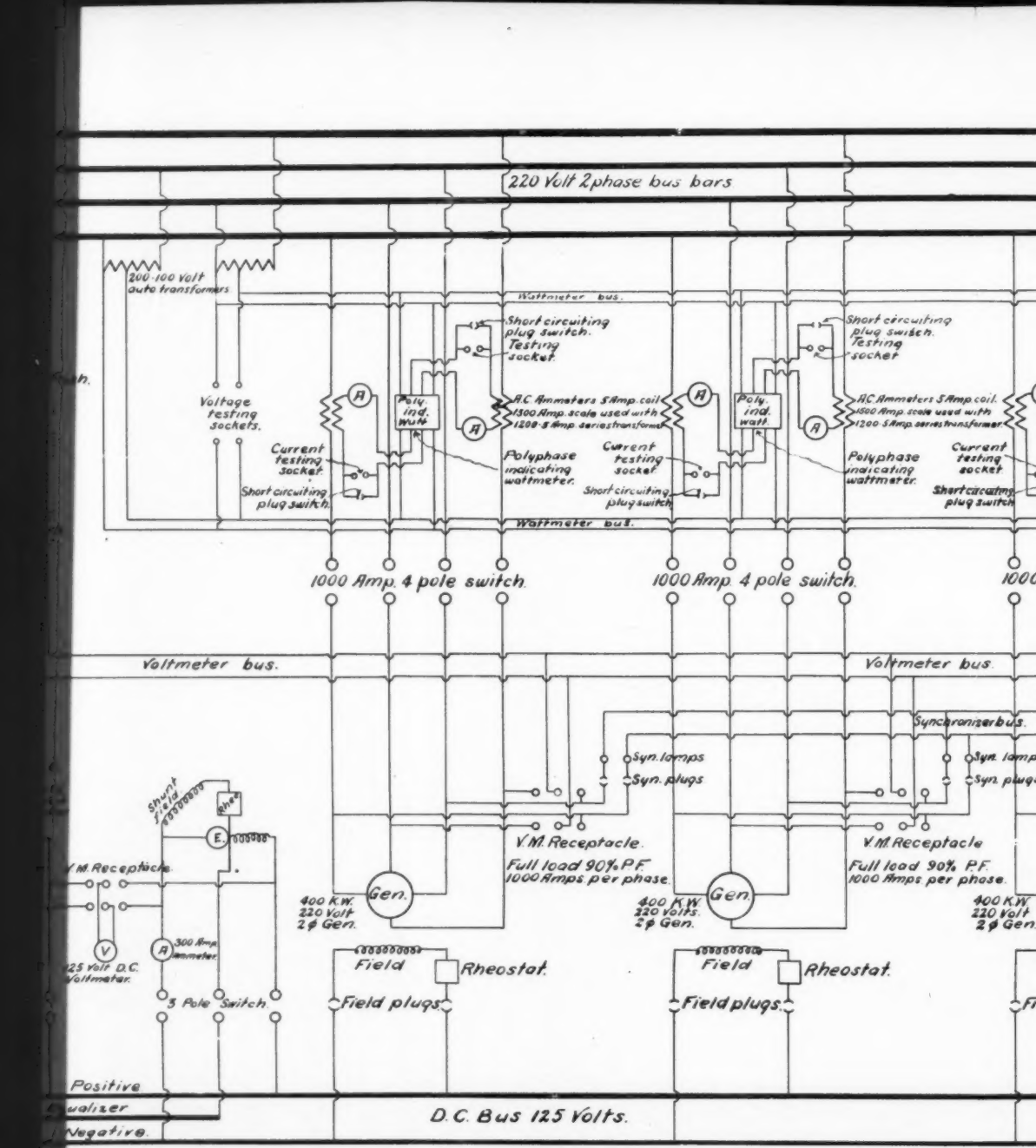

220 Volt 2phase bus bars
200-100 Volt auto transformers
Wattmeter bus.
Short circuiting plug switch. Testing socket.
Voltage testing sockets.
Poly. ind. watt.
A.C. Ammeters 5 Amp. coil 1500 Amp. scale used with 1200-5 Amp. series transformer
Current testing socket
Short circuiting plug switch.
Polyphase indicating wattmeter.
1000 Amp. 4 pole switch.
Voltmeter bus.
Synchronizer bus.
Syn. lamps
Syn. plugs
V.M. Receptacle.
Full load 90% P.F. 1000 Amps. per phase.
400 K.W. 220 Volt 2φ Gen.
Gen.
Shunt field
Rheostat
E.
300 Amp. Ammeter
125 Volt D.C. Voltmeter.
3 Pole Switch
Field
Field plugs
Positive
Equalizer
Negative
D.C. Bus 125 Volts.

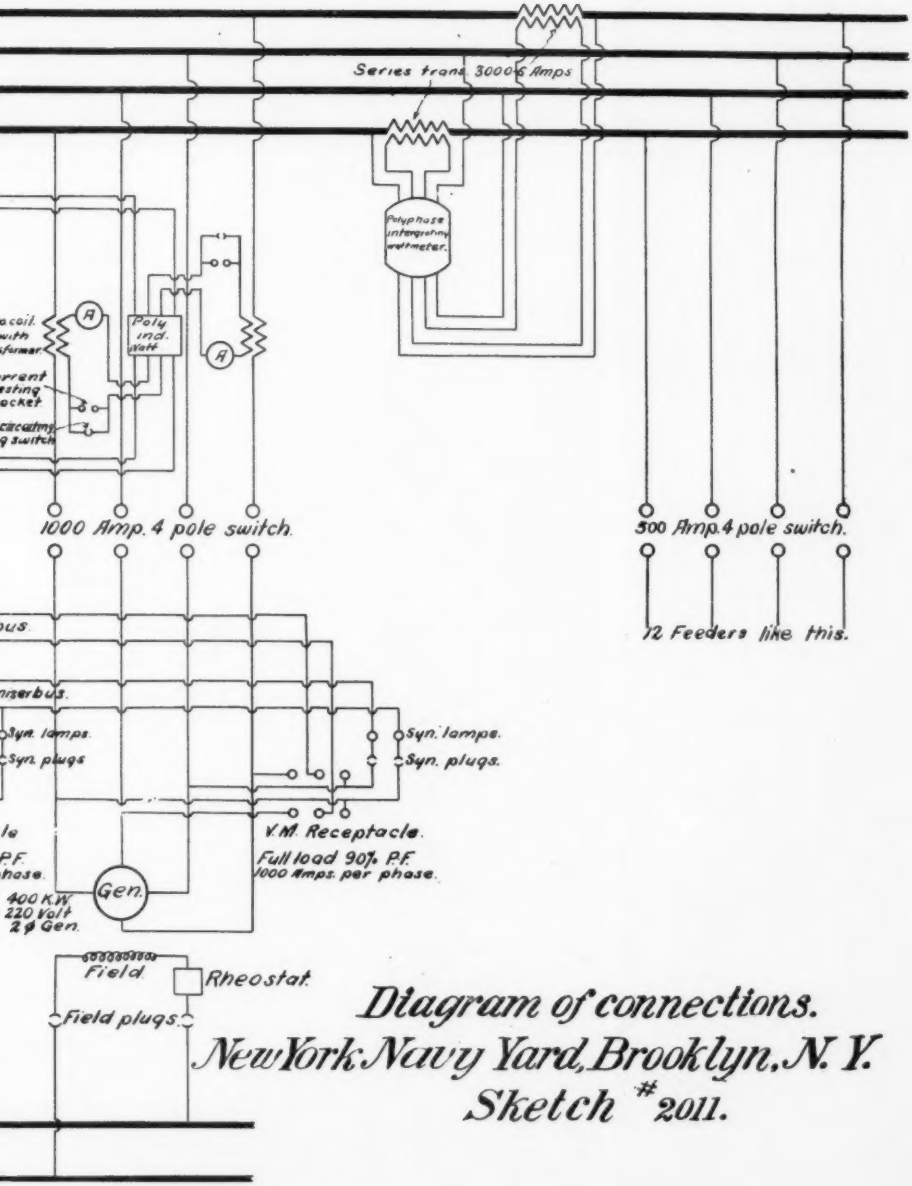


Diagram of connections.
New York Navy Yard, Brooklyn, N. Y.
Sketch # 2011.

at the higher speed a capacity of 7½ horsepower and at the lower speed a capacity of 3¾ horsepower. The motor is mounted on an extension of the bed plate which carries the three vertical-pump cylinders, and is connected to the main shaft driving the three pistons by a double reduction gearing, the pump running at a speed of 32 or 16 revolutions per minute.

In the boiler room, three main motors are installed, a 5-horsepower motor for the Roney stokers, a 15-horsepower motor for the coal and ash-handling machinery, and a 20 horsepower motor for driving the fan of the mechanical-draft system, all being connected to the apparatus which they drive through reduction gearing having the proper ratio.

Two 3-horsepower alternating-current motors of the same general type, but arranged with vertical shafts, are installed in the peak of the boiler-room roof to operate ventilating fans. The fans are pressed directly on the motor shaft and are designed to run at a speed of 710 revolutions per minute.

All of the motors driving the auxiliary machinery in the power house are controlled by special auto-starter panels, the detail construction and operation of which is given below. For driving the various machine tools and the short lengths of countershafting, to which latter the smaller tools are belted, there are installed in the various shops an approximate total of 60 alternating-current two-phase motors, ranging in capacity from 1 to 30 horsepower, inclusive, and wound for various speeds, at 3,000 alternations, 200 volts, to meet the requirements of the machines to which they are connected.

A 200-horsepower motor is also in service, driving a large air compressor, built by the Rand Drill Co., by means of which power is furnished to the various pneumatic tools. All of these motors, together with those in the power house, are of the standard Westinghouse design, and are known to the trade as the constant-speed "Type C" motor. As shown in the various illustrations, this motor, from a mechanical point of view, is of exceedingly simple design and construction.

The stationary element is permanently connected to the main circuit, and the rotating part, being without electrical connection

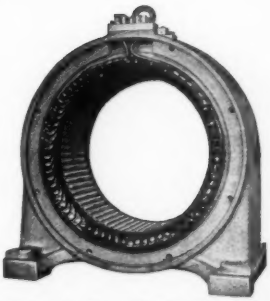
to any external circuit, the necessity of sliding or brush contact and the resulting friction is thereby avoided; in fact, the only friction in the motor is to be found in the journal boxes, and even this is reduced to a minimum, owing to the balance in which the revolving element is magnetically kept when the motor is in operation. The stationary element of the motor, more properly known as the primary, consists essentially of a cast-iron yoke which is so designed that it forms a base for the machine and also supports the end brackets carrying the bearings. The primary core is built up on the inside of this yoke of thin steel punchings, arranged to receive the primary winding. The laminations are held in place by two end rings, sprung into grooves machined to receive them on either side of the yoke casting. The primary conductors are machine-wound wire coils, which are thoroughly insulated to withstand a puncture test of an alternating electro-motive force of 1,500 volts before being put in the core slots. The grouping of these coils depends upon the speed at which the motor is to operate and the consequent necessary number of poles. In the two-phase motor there are two sets of entirely independent winding, one for each phase, and connections are made to two sets of terminal blocks, of two each, located on the top of the motor yoke. The revolving or secondary element of the motor is, with the exception of the winding, of the same general construction as the primary. There is a cast-iron frame work, the spider, on which is built up the secondary core. This core consists of a large number of circular punchings of thin sheet steel, which are placed on the spider and held in position by means of end plates.

The secondary winding consists of insulated copper bars, which are slipped into place from the side; hence, the core teeth are arranged with overhanging tips, which construction obviates the necessity of providing any other means for securing the secondary bars and preventing their being thrown out by centrifugal force when the motor is running at a high rate of speed.

The secondary bars are bolted at either end to cast-brass resistance rings, so that each bar is short circuited, and from this

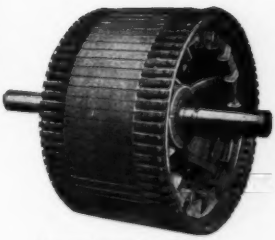
Cast-iron Housing.

Primary Ready for Winding.

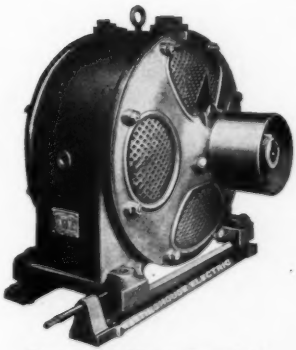


Primary Completely Wound.

Secondary Core.

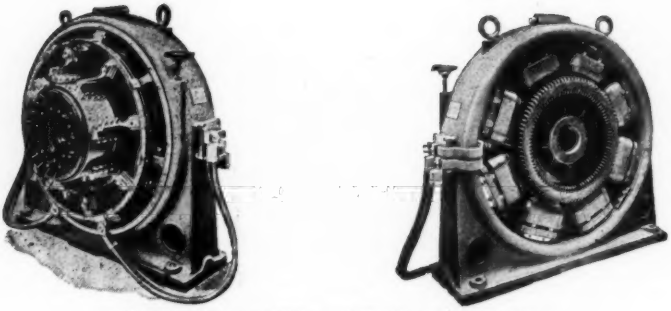


Secondary Complete.

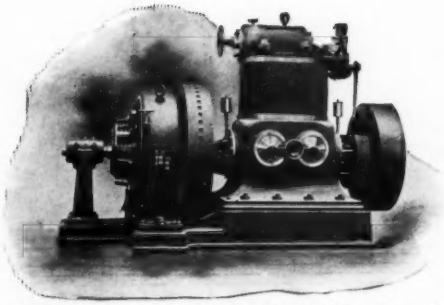


Type "C" Motor Complete.

CONSTRUCTION OF A TYPICAL TYPE "C" MOTOR.



Westinghouse 25-Kilowatt Engine-Type Exciter.



Engine-Type Exciter, Direct-connected to the Westinghouse Steam Engine.

construction the winding, as a whole, has been given the name of the " squirrel-cage" type.

The secondary spider is pressed on the motor shaft and the shaft is supported by self-aligning bearings placed in the end brackets. Oil wells are provided in each of these brackets and, by means of a number of oil rings, the motor is made self-lubricating.

Throughout the primary and secondary cores a large number of ventilating ducts are provided, and the spider and revolving resistance rings are so designed as to set up a forced circulation of air through these ducts and around the primary coils. By this means the temperature of the motor, even when operating on heavy overloads, is kept very low.

As already pointed out, the only wearing surfaces are those of the shaft and bearings, and, by the construction as just outlined, a renewal of these parts is very simple, the shaft being readily pressed out of the spider and a new one substituted. One of the most attractive features of this type of motor is the possibility of operating it when supported in any position; that is, the motor may be bolted to the floor, to the ceiling, or to a plane at an angle of 45 degrees thereto.

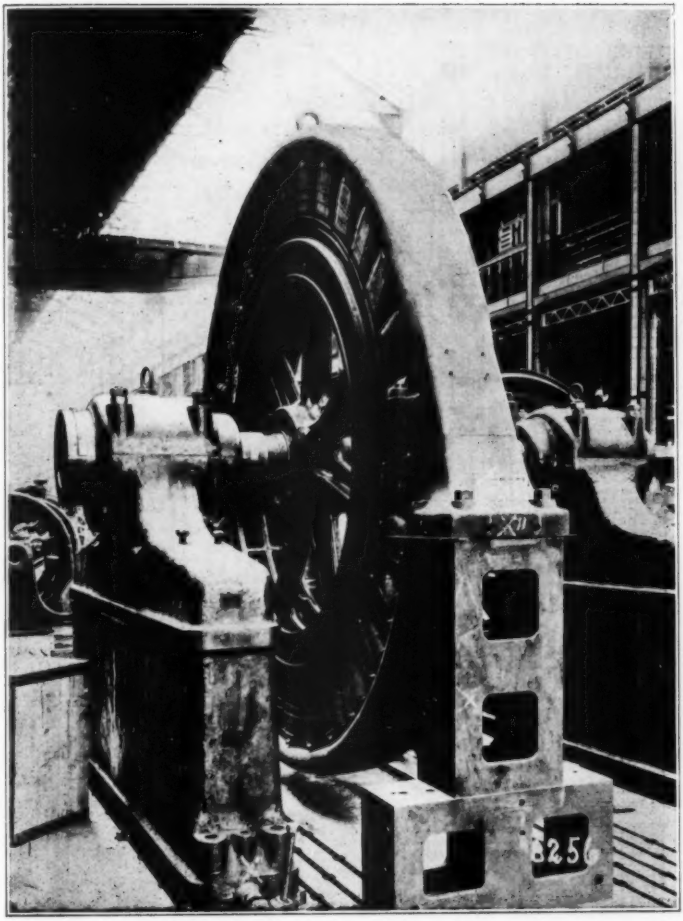
When placed in any position other than on the floor, the only change that is necessary is to arrange the oil wells so that the oil will not be spilled. The end brackets are secured to the yoke by means of eight stud bolts, which are accurately spaced the same distance apart around the edge, and the brackets may, therefore, be turned to any position made necessary by the position in which the motor is placed.

The principle of operation employed in the " Type C" motor is too well understood to need detailed explanation, but it may be of interest to review, briefly, the principal points thereof. The primary winding is arranged with its coils grouped into a number of pairs of poles, this number being determined by the required speed of the motor.

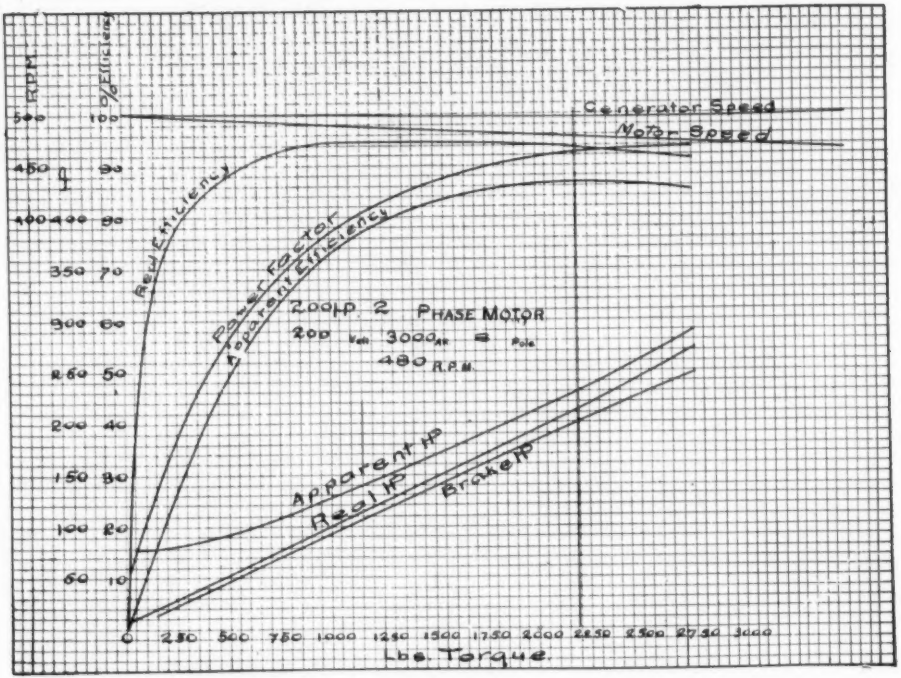
Polyphase alternating currents flowing in these groups of coils set up a revolving field, the speed of which, per pair of poles, depends upon the alternations of the circuit.

In the short-circuited secondary winding induced currents are set up, having a very low electro-motive force, and rotation of the secondary is produced through the reaction between these currents and the primary currents. The current taken from the line by an alternating-current motor operating at a given load is comprised of two elements, the working current and the magnetizing or wattless current. The value of the former is determined by the load which the motor is carrying, and may be calculated by the application of Ohm's law, as in the case of a direct-current motor. This current is in phase with the electro-motive force of the circuit, being at a maximum value when the voltage is at a maximum and at a minimum value when the voltage is at a minimum. The magnetizing current is a lagging current, flowing a quarter of a period behind the electro-motive force, its maximum value occurring when the electro-motive force is zero. This current is practically constant at all loads, the only variation being due to the effect of the magnetic leakage in the primary winding. This leakage causes a stray magnetic field, which has a choking effect on the secondary currents, and, therefore, further increases the lagging or magnetizing current required by the motor. The magnetic leakage is practically negligible at light loads, increases with the load, and is of a large value when the motor is operating on overloads. The amount of magnetic leakage in a motor is dependent on the design thereof, and in the Type C motor it has a small value. The importance of this feature is readily understood, as it is well known that the variation in the line drop, due to a motor operating at varying loads, is small if the lagging current to the motor is constant. The demands on the generator are, therefore, less severe, and better regulation is obtained than if the magnetizing current varied between wide limits.

The working current is itself made up of two elements—that which is used to drive the motor load and that expended in heating, friction losses, etc. To obtain the total working current these two currents may be simply added together. Inasmuch as the wattless current to a motor is not in phase with the electro-motive force and the working current has this relation, it follows



WESTINGHOUSE ALTERNATING–CURRENT ENGINE-TYPE GENERATOR.



PERFORMANCE CURVE OF 200 H.P. TYPE "C" MOTOR.

that the resultant total current is not the arithmetical sum of the two currents, but rather the square root of the sum of the squares thereof, the lagging current being 90 degrees behind its electromotive force. In other words, using a geometrical construction, the total current may be found by determining the value of the hypotenuse of a right-angled triangle, of which one side represents the magnetizing current and the other the working current. The relation between the working current and the total current taken by the motor is known as the power factor thereof. This relation, of course, increases with the load, and at no load the power factor is very low, the magnetizing current being then of major importance, and the working current only that required to overcome the bearing friction and that expended in other losses.

The performance curves as shown of the 200-H.P. motor used to drive the Rand air compressor illustrate this relationship very clearly, and also show the general performance of the machine. In these curves the torque exerted by the motor at a radius of 1 foot, or the belt pull from a 24-inch pulley, is plotted as abscissa, the horsepower, efficiency, power factor, etc., as calculated from instrument and brake readings being plotted as ordinates.

The power factor at which a motor will operate at a given load must not be confused with its efficiency at that load, nor must the apparent energy be confused with the real energy applied.

The magnetizing current is strictly a wattless current, and to produce it no power is required in the engine or water wheel driving the generator from which the power is obtained. The power factor at which a motor is operating affects its efficiency, however, inasmuch as a lagging current increases the primary copper loss. This increased loss is, however, so small for ordinary power factors as to be almost negligible.

The efficiency of the motor depends, of course, on the losses therein, and in the Type-C motor there is to be considered the primary iron loss, the primary copper loss and the secondary copper loss, the two latter being strictly heat losses, as is also the greater part of the former. In a given motor operating at a constant voltage, the primary iron loss is practically constant,

independent of the load, as is also that portion of the primary copper loss due to the magnetizing current and friction. The other losses—the primary copper loss due to the working current and the secondary copper loss depending on the slip of the motor or variation from synchronous speed—increase as the square of the motor load.

It will be noted, on reference to the performance curves of the 200-horsepower motor, that the efficiency and power factor is very high, and especially so at loads between three-fourths load and full load. The efficiencies and power factors of all of the smaller motors installed are correspondingly high.

The motors are designed very liberally with respect to temperature limits, being guaranteed to carry their rated full load continuously with a rise in no part to exceed 40 degrees centigrade above the surrounding air. They will also carry a 25-per cent. overload continuously with a rise not exceeding 50 degrees centigrade, and an overload of 50 per cent. for a period of one hour with a rise not exceeding 60 degrees centigrade; further, the motors will exert a torque 100 per cent. above full-load torque for a period of ten minutes, and may be locked for one minute without injury.

Upon again referring to the curve of the 200-horsepower motor, it will be noted that when running at full load the torque is about 2,200 pounds at a radius of one foot. The starting torque of this motor, normal electric motive force, 200 volts, being applied to the terminals, is approximately three times full-load torque, and the maximum running torque is approximately three and one-half times full-load torque.

The torque exerted by Type C motors as a class is at starting, as in the case of the 200-horsepower motor, several times the value of the full-load torque. This is considerably higher than is required or desirable for motors used in ordinary machine-shop practice, as the driven tools are usually started without load, and, further, the resulting mechanical shock to the machinery is to be avoided. Another point to be considered is that, with the use of lower starting torques, the starting current taken by the motor is reduced, it being proportional to the starting torque,

and for full-load torque about two and one half times full-load current.

The starting torque is a function of the voltage applied to the motor, varying as its square. By means of a pair of auto-transformers placed between the line and the motor the electro-motive force at starting may be lowered as desired, and the torque correspondingly reduced. All of the motors installed in the navy yard are equipped with devices of this kind, except those of a capacity below 5 horsepower, in which cases there is no necessity for their use. Each of these consists of a marble panel, on which are mounted the necessary controlling switches and two auto-transformers, which latter are mounted in separate cast-iron cases and arranged to be placed apart from the panel and connected thereto.

Each of these starting panels carries a four-pole double-throw switch for throwing a low voltage on the motor terminals at starting, and, when full speed has been reached, applying full-line voltage by throwing to the other position; also, a main four-pole single-throw switch for cutting the motor entirely from the circuit, and, in some cases where it is necessary to run the motors in either direction, a two-pole double-throw reversing switch. The two auto-transformers are connected between one side of the starting switch and the motor, and are provided with a number of loops. By this means the electro-motive force applied at starting may be reduced at will to meet the requirements of the service on which the motor is working.

When it is desired to stop the motors, the circuit is broken by means of the four-pole single-throw main switch, except in the case of the large motor, where circuit breakers are provided for this purpose on the starting panel.

The entire plant as described, while designed from an electrical point of view in accordance with the most advanced ideas, can in no wise be considered as experimental. Standard apparatus is used throughout, thus making duplications or possible renewals very easy, and the plant as a whole is in many respects similar to numerous others which have been installed, and which are giving perfect service and the highest satisfaction to their owners.

NOTES.

SEA TRIALS OF H. M. S. *HYACINTH* AND *MINERVA*.—REPORT OF THE BOILER COMMITTEE.

Since the last issue of the JOURNAL there has been received the report in full of the sea trials of H. M. S. *Hyacinth* and *Minerva*, which is as follows:—

REPORT ON THE TRIALS OF HIS MAJESTY'S SHIPS *HYACINTH* AND *MINERVA* TO GIBRALTAR AND BACK, JULY 6–20, 1901.

RETURN OF THE PARTICULARS OF THE RECENT SEA TRIALS OF THE *MINERVA* AND *HYACINTH*.

FIRST LORD:

I forward herewith the observations of the President of the Boiler Committee on the most recent trial of the *Hyacinth* and *Minerva*. For convenience of comparison in respect of coal and water consumption I append the statistics of the previous trials, and I wish to draw your attention to the following points in this trial:—

(1.) The very serious loss of water in *Hyacinth*, as pointed out by the President of the Boiler Committee. This was due to leaky joints. A certain number were located at Gibraltar, and on examination at Portsmouth other leaks were discovered and reported (see report of Portsmouth Yard Officers).

(2.) The state of the *Minerva's* tubes at the end of each run. On arrival at Gibraltar the cap ferrules were found to be partially choked due to bird-nesting, and the ship could not have gone any further at that power (7,000 I.H.P.). As it was, she was using up to 1.7 inches of air pressure instead of ½ inch to maintain the necessary combustion for this power. On arrival at Portsmouth practically the same thing occurred, as will be seen from the reports.

(3.) The *Hyacinth* developed an average of 1,000 more indicated horsepower than the *Minerva* on the run home; this should

have given the former a substantial increase in speed, whereas there was a slight decrease. This extra I.H.P. must have been absorbed either in the engines, or on the main-shaft bearings, or in the hull. It is possible that the shape of the hull may have had something to say in the matter, but former trials do not bear this out. For example, when the *Highflyer* (same class) was tried against the *Minerva* last year, the former maintained a higher power and speed, except at 10 knots, when she had to exert more I.H.P. to obtain the speed (see Memorandum respecting Water-tube Boilers, pages 22, 23, &c., presented to Parliament last year). The case requires investigation.

W. H. MAY, *Controller of the Navy.*

31st July, 1901.

26th July, 1901.

Sir: Be pleased to submit to their Lordships the enclosed report of the trials of the *Hyacinth* and *Minerva* to Gibraltar and back.

I have refrained from expressing any opinions in this report, as I have not yet been able to arrange for a meeting of this Committee to discuss the results.

The figures quoted in this report are those recorded on board the ships, and will be liable to slight alteration when the results are worked out in the office.

I am, &c.,

COMPTON DOMVILE, *Vice-Admiral,*
President of Boiler Committee.

THE SECRETARY OF THE ADMIRALTY.

STATEMENT BY PRESIDENT OF THE BOILER COMMITTEE.

Representatives of the Boiler Committee, consisting of the President, three Members, and the Joint Secretaries, embarked in H. M. S. *Hyacinth* and *Minerva* at Devonport, about 2 P. M. on the 6th July. The ships sailed at about 3 P. M. on that day, and started working up to 7,000 H.P. It was intended that the ships should maintain 7,000 H.P. till all the coal, except that in the reserve bunkers (82 tons), was exhausted. By 3·45 P. M. the revolutions in the *Hyacinth* were 152 per minute and the H.P.

HYACINTH AND *MINERVA*.—BOILER-COMMITTEE TRIALS CARRIED OUT PREVIOUSLY TO GOING TO GIBRALTAR.

—	Duration of trial in hours.	IHP.	Boiler performance. Actual evaporation of water per lb. of coal.	Boiler performance. Comparison.	Engine performance. Water used per I.H.P. per hour. Main.	Aux.	Jackets.	Make-up.	Total.	Engine performance. Comparison.	Combined performance. Coal per I.H.P. per hour.	Combined performance. Comparison.	Remarks.
Hyacinth... 2,000	24½	2,049	9.64	*Hyacinth* evaporated 12.62 per cent. more than *Minerva*.	1st 18 hours with closed exh. and L.P. jackets. 18.436		.222	.513	19.191	*Minerva* used 5.97 per cent. less than *Hyacinth*.	2.03	*Minerva* burned 5.81 per cent. more than *Hyacinth*.	The records for *Minerva* gave a total amount of .484 lbs. per hour per I.H.P. for "make-up" and jacket use. The division shown is based on subsequent records of these quantities taken separately.
					Last 6½ hours with open exh. and with jackets. 16.864	2.920	.331	.513	20.628				I.H.P. Tons.
Minerva ...	25	2,142	8.56		15 903	2.016	.284	.200	18.403		2.148		*Hyacinth*, water lost per day per 1,000 = 5.5
													Minerva, water lost per day per 1,000 = 2.14
Hyacinth... 5,000	24	4,995	9.37	*Hyacinth* evaporated 5.64 per cent. more than *Minerva*.	1st 12 hours closed exh. and L.P. jackets. 16.777		.227	.258	17.262	*Minerva* used 10.56 per cent. less than *Hyacinth*.	1 84	*Minerva* burned 5.43 per cent. less than *Hyacinth*.	† These results show a gain of 3.94 per cent. due to use of closed exhaust in L.P. receivers, which would make *Minerva* use only 8.7 per cent. less total water than *Hyacinth*.
					Next 6 hours closed exh. and no jackets. 16.645		.....	.258	16.903†				I.H.P. Tons.
					Last 6 hours open exh. and no jackets. 15 557	1 781	.....	.258	17.596†				*Hyacinth*, water lost per day per 1,000 = 2.76
Minerva ...	24	5,155	8 869		13.404	1.331	.417	.280	15.432		1.74		*Minerva*, water lost per day per 1,000 = 3.00
Hyacinth... 8,000	12	8,116	9.85	*Hyacinth* evaporated 23.74 per cent. more than *Minerva*.	8 hours closed exh. in use; jackets not in use. 17.673		.....	.511	18.184‡	*Minerva* used 5.95 per cent more than *Hyacinth*.	1.84	*Minerva* burned 31.08 per cent more than *Hyacinth*.	‡ These results show no appreciable difference by use of closed exhaust at this power.
					4 hours with open exhaust; jackets not used. 15.785	1.731	....	.511	18.027‡				I.H.P. Tons.
Minerva ...	9	8,132	7 96		16.309	2.197	.356	.348	19.210		2.412		*Hyacinth*, water lost per day per 1,000 = 5.57
													Minerva, water lost per day per 1,000 = 3.73
Hyacinth... 10,000	8	10,180	8.85	.....	16.404	1.828	.....	.452	18.684	.....	2.11	.....	Special trial at 10,000 I.H.P. Water lost per day per 1,000 I.H.P. = 4.84 tons.
Minerva ...	9	8,132	7.96	11.05 per cent. more water evaporated by using retarders	16.309	2.197	.356	.348	19.210	Used with retarders 8.83 per cent. less than without.	2.412	Burned with retarders 17.9 per cent. less than without.	*Minerva's* trials made with and without retarders. The special trial at half power (4,771 I.H.P.) made with half number of boilers showed a gain in evaporation of 11.05 per cent., due to the use of retarders. These were fitted to all *Minerva's* boilers before trip to Gibraltar.
Minerva ...	8½	4,771	8.84		14.846	1.726	.595	.345	17.512		1.98		

6,994, and the trial was considered to have started from that time. The *Minerva's* trial commenced at 4 P. M. The *Minerva* soon showed that she was the faster ship and steadily drew away from the *Hyacinth*. By midnight on the 7th the *Minerva* was about 4½ miles ahead.

When passing through the Straits of Gibraltar, early in the morning of the 9th, a fog was encountered, the *Minerva* eased down for 55 minutes, while the *Hyacinth* had to ease down for two hours. On running out of the fog both ships again worked at 7,000 H.P.

At 4·30 P. M. on the 10th July, a bolt of the ahead eccentric strap of the starboard intermediate engine of the *Minerva* broke, and the starboard engines had to be stopped; the port engines continued running. The strap was found to be damaged and had to be replaced by the spare one. This work was carried out in about two hours, and at 6·40, the starboard engines started working again, and were worked up to the required power.

It had been arranged that the water in the reserve tanks of both ships should be used as the only make-up feedwater until it was reduced to 20 tons, in order that the amount of make-up feed used per day might be accurately determined. When the reserve had been reduced to 20 tons, this water was to be kept intact in the tanks ready for use in case of emergency, and all make-up required was to be obtained from the evaporators.

Special reserve tanks had been fitted in the *Hyacinth* to hold about 100 tons; this, added to the original reserve-tank stowage, gave a total reserve-tank stowage of about 140 tons. The total reserve stowage of the *Minerva* was about 170 tons.

When the amount was reduced to 35 tons in the *Hyacinth*, the Staff Engineer asked to be allowed to start the evaporators on account of the difficulty of getting the water out of the tanks by the special pump fitted for these trials. Two Weir's evaporators working with exhaust steam were started at 5.30 A. M. on the 9th, and the two Normandy's during the afternoon of the 10th.

At 1·15 A. M. on the 11th July, the Staff Engineer of the *Hyacinth* reported the engines would have to be eased on account of the large loss of water, and the trial was abandoned

from 1 A. M. All the evaporators were working at this time, and in addition to the water from the reserve tanks, 25 tons of drinking water had been used for boiler make-up. The *Hyacinth* returned to Gibraltar at slow speed, arriving there on the evening of the 11th.

The *Minerva* continued steaming at 7,000 H.P. till 11 P. M. on the 12th, at which time there were still 39 tons of coal in the bunkers, not including the reserve, and 20 tons of water remained in the reserve tanks.

The average H.P. of the *Hyacinth* was 7,047 for 103¼ hours, with a coal consumption of 1.97 pounds, and the distance run was about 1,810 miles at an average speed of 17.6 knots; the *Minerva's* H.P. was 7,007 for 147 hours, with a coal consumption of 2.06 pounds, and the distance run was about 2,640 miles, at an average speed of 17.96 knots.

On the night of the 10th July, flaming occurred at the after funnel of the *Hyacinth*, but no flaming is reported from the *Minerva*. On examination of the *Minerva's* boilers after arrival at Gibraltar, it was found that the openings in the Admiralty ferrules were seriously choked, the size of the openings, in some cases, being reduced to about one-third the original.

The boilers and engines in both ships worked well on the way out, with the exception of the eccentric-strap bolt of the *Minerva*, and a number of leaks which developed in connection with the boilers of the *Hyacinth*; these latter appeared to become worse after the engines were suddenly eased on entering the fog on the 9th, on which occasion the pressure of the boilers became sufficiently high as to lift the safety valves.

The loss of water in the *Hyacinth* was at first attributed to leaky feed-suction pipes, but during the stay at Gibraltar these pipes, the feed and hotwell tanks, and the boilers and boiler blow-outs, were water-pressure tested, and no leaks beyond those already known to exist in the boilers were discovered.

As no serious leaks could be discovered during the stay at Gibraltar, the leaky joints in the *Hyacinth's* boilers were re-made by the ship's staff; and, on Tuesday 16th, the ship was taken

out for a run at about 7,000 H.P., to test the amount of feed water being lost. This was found to be at the rate of 55 tons a day, from the records of a six hours' run ; after being under way three hours, the engines were eased by order from the deck, and the boiler safety valves allowed to blow off freely, so as to reproduce the circumstances that occurred in the fog on the 9th July. The rate of loss of water was calculated from a steady three hours' run before easing and a steady three hours' run after easing, a fresh start being made after easing down, and the water lost during the period the safety valves were allowed to blow being neglected. On return, the *Hyacinth* anchored in the bay at 4·30 P. M., and all fires were drawn except those in two boilers. The *Minerva* steamed from the Mole with three boilers alight and anchored in the bay at about the same time as the *Hyacinth* anchored ; fires were drawn from two boilers.

Gibraltar dockyard made a spare eccentric strap for the *Minerva* and supplied it to the ship on morning of 17th.

At 3·30 P. M. on the 17th, the Committee embarked. At this time the *Hyacinth* had two boilers alight for auxiliary purposes, and the *Minerva* one.

The boilers of both ships had been thoroughly cleaned during the stay at Gibraltar.

Before the ships began the homeward run, a communication as follows was handed to the captain of each ship :—

"On the responsibility of the ship's officers, a large quantity of fresh water for boiler make-up has been taken as a precautionary measure in the double bottoms of the *Hyacinth* and in the extra reserve tanks of both ships. These latter tanks were fitted specially for the outward trials, and do not form a part of the ship's ordinary fittings. It is to be understood that, except the amount originally allowed to each ship (about 40 tons in the ordinary reserve tanks), this is to be used in cases of emergency only during the homeward run. The evaporators, if they have not been in use before, are to be started as soon as the 40 tons mentioned have been used up, and then the make-up required is to be obtained from the evaporators. If the evaporators are unable to supply the whole of the make-up required, their use at

maximum obtainable output is to be maintained while the remaining water used may be taken from the reserve tanks."

In the case of the *Minerva*, the expenditure of the 40 tons in question was not exceeded, but the *Hyacinth* had used the 40 tons by 5·15 A. M. on the 20th, although her evaporators had been working practically all the time.

At the conclusion of the trial it was reported that 98 tons of water had been used from the reserve tanks of the *Hyacinth* as make-up feed, in addition to that made by the evaporators.

The ships were informed that on the signal being made at an unknown time after 4·00 P. M. by the senior officer at Gibraltar, fires were to be lighted in the boilers not at work, and the ships were to proceed to Portsmouth as fast as possible. The signal was actually given at 4·27 P. M.

The engines of both ships had been warmed through by steam from the boilers alight.

At 4·30 P. M., the *Hyacinth's* engines were worked slowly in accordance with orders from the deck, steam being supplied by the two boilers which were alight. At 4·52 the after group of boilers was connected up. At 5·5 the forward group and at 5·9 the middle group were connected up, the steam pressure being 200 pounds. At 5·20 P. M. the *Hyacinth* was proceeding at 150 revolutions per minute, the H.P. being nearly 7,000.

At 4·30 P. M. the *Minerva's* engines were worked slowly in accordance with orders from deck. The boilers were connected at the following times :—

2d, 4·55; 3d, 5·2; 4th, 5·7; 5th and 6th, 5·10; 7th, 5·12; 8th, 5·15.

The engines were working up to full power at 5·16 P. M., but had to be eased several times between 5·30 P. M. and 8 P. M., on account of eccentric straps warming up.

At 5·15 A. M. on the 18th the *Hyacinth* was about six miles ahead of the *Minerva;* but, both ships running into a fog, the *Minerva* ran up to the *Hyacinth*, and at 9·30 A. M., on the 18th, on emerging from the fog, the ships were nearly level, the *Minerva* being slightly ahead. Both ships then worked up to the maximum power, but throughout the day the *Minerva* was stated

to have gained one-third of a knot an hour on the *Hyacinth*. At 7 P. M., another fog was encountered, and the ships went slow throughout the night, keeping close to each other.

At 9 A. M. on the 19th they were again level. The fog having cleared, both ships went on again, and during the day the *Minerva* gradually drew ahead and was stated to be going a quarter of a knot an hour faster than the *Hyacinth*. At 7 P. M. the *Hyacinth* again eased owing to fog, and went slow till 5 A. M. on the 20th, the *Minerva* being out of sight ahead.

The *Hyacinth* then steamed at over 9,000 H.P. till 6·10 P. M. on the 20th, when the fires of No. 10 boiler were drawn on account of a burst tube; one man was slightly injured by the steam and hot coal.

At 9·50 P. M. the trial in the *Hyacinth* finished, the ship being then off St. Catherine's, and she arrived at Spithead at 11·30 P. M. The *Minerva* had passed St. Catherine's at 8·20 P. M. and anchored at Spithead at 9·45 P. M.

The coal used by the *Hyacinth* on the way home was stated to be 550 tons; by the *Minerva*, 451 tons.

The *Hyacinth's* evaporators were all in use practically the whole time, but the *Minerva* used hers but little.

The maximum power developed by the *Minerva* was about 8,700 H.P., while that developed by the *Hyacinth* was nearly 10,000 for at least two hours, during which time the *Hyacinth* did not perceptibly gain on the *Minerva*. The *Hyacinth's* average power when running clear of fog was about 9,400, and the *Minerva's* about 8,400 H.P.

From the results of the outward run it appears that the radius of action of each of these vessels at 7,000 H.P., as far as the coal is concerned, should be, roughly—

Hyacinth, 2,930; *Minerva*, 3,000 miles.

No difficulty was experienced in either ship, at any part of the outward or homeward runs, in keeping up a sufficient supply of coal to the fires.

COMPTON DOMVILE, *Vice-Admiral*,
President of Boiler Committee.

July 26th, 1901.

TABULATED STATEMENT OF RESULT OF EXAMINATION H. M. S. *HYACINTH*.

No. of boiler.	Nos. of elements in which bottom tubes are bent. (a) Curved upwards.	Amount.	(b) Sagged.	Amount.	Feed collectors.	Junction box doors leaking.	Remarks.
		inch.		*in.*	*inch.*		
1	6, 7 and 8	$\frac{1}{8}$	...	...	Hollow on fire side, $\frac{3}{16}$	5	
2	9	$\frac{3}{16}$	...	...	Hollow on fire side, $\frac{5}{16}$	6	
	3, 6 and 7	$\frac{1}{4}$	...	...			
3	3, 4, 5 and 9	$\frac{1}{4}$	...	...	Hollow on fire side, $\frac{1}{4}$	8	
4	1	$\frac{1}{4}$	...	...	Hollow on fire side, $\frac{1}{8}$	11	Fusible plug in water space, No. 9 element, leaking.
	7	$\frac{3}{16}$	...	...			
	8	$\frac{1}{4}$	...	...			
5	2 and 7	$\frac{1}{4}$	...	...	Hollow on fire side, $\frac{1}{4}$	3	Fusible plug in water space, No. 7 element, leaking.
	4 and 8	$\frac{5}{16}$	...	...			
	...	...	4 (second tube)	$\frac{5}{16}$			
6	4, 5 and 7	$\frac{1}{4}$	...	...	Hollow on fire side, $\frac{1}{8}$	3	Spigot joint on No. 4 element leaking slightly.
	3 and 6	$\frac{1}{4}$	...	...			
7	1 and 6	$\frac{5}{16}$	...	...	Hollow on fire side, $\frac{3}{16}$	5	
	5, 7 and 8	$\frac{1}{4}$	...	...			
	3	$\frac{1}{4}$	...	...			
8	1 and 6	$\frac{3}{16}$	...	...	.....	3	
	7	$\frac{1}{8}$	...	...			
9	1, 6 and 8	$\frac{1}{4}$	...	...	Hollow on fire side, $\frac{1}{8}$	2	Check nut leaking, top of starboard downscast pipe.
	4	$\frac{5}{16}$	...	...			
	5	$\frac{1}{4}$	...	...			
	7	$\frac{1}{4}$	...	...			
10	*See* end of table.						

11	...	...	1 Bottom tube...	7/16	Hollow on fire side, 1/4	2	Sight door on starboard elbow leaking slightly. Mudhole door bottom of steam collector leaking slightly.
			Second tube...	3/16			
	...	...	2 Bottom tube...	1/16			
			Second tube...	1/4			
	...	...	3 Bottom tube...	3/16			
			Second tube...	1/16			
	...	...	4 Bottom tube...	1/8			
			Second tube...	5/16			
	...	...	5 Bottom tube...	1/8			
			Second tube...	1/8			
	6 and 8	1/8	...	...			
12	3 and 6	3/16	...	...	Hollow on fire side, 1/4	5	Sight door on starboard elbow leaking slightly.
	1	1/8	...	...			
	9	1/16	...	...			
13	2, 5 and 9	1/8	...	...	Hollow on fire side, 1/8	6	Sight door on port elbow leaking.
	1	3/16	...	...			
14	Bottom 1, 5 and 8 bottom 2d	1/8	...	...	Hollow on fire side, 1/16	6	Fusible plug in No. 9 element leaking. Sight door and spigot joint on port elbow leaking.
15	1 and 9	1/8	...	...	Hollow on fire side, 1/4	16	Sight door on port elbow leaking. Sight door on top of starboard downcast pipe leaking.
16	...	...	...	...	Hollow on fire side, 1/8	1	Sight door on pt. elbow leaking slightly. Door on feed distributing box leaking slightly.
17	1, 7 and 9	1/8	...	...	Hollow on fire side, 1/8	...	Sight door on top of starboard downcast pipe leaking slightly. Manhole door starboard end of steam collector leaking slightly.
	4 and 5	3/16	...	...			
	3 and 6 bottom tube and 2d tube	1/8	...	...			
18	...	...	...	...	Hollow on fire side, 1/8	...	
10	...	...	1 Bottom tube...	1/8	Hollow on fire side, 3/16	...	Spigot joint on port elbow leaking.
			Second tube...	3/16			
	...	...	4 and 6—2d tube..	1/16			
	...	...	5 Bottom tube...	3/16			
			Second tube...	1/8			

The doors have been removed from the lower tubes in Nos. 11, 16 and 17 boilers, and the condition of the tubes found to be clean and in good order.

NOTES.

REPORT OF PORTSMOUTH DOCKYARD OFFICERS.

The boilers of *Minerva* and *Hyacinth* have been examined with the following result:—

Minerva.

An external examination only of the boilers was made (boilers not having been opened out).

The cap ferrules in all boilers were found partially closed with "bird nesting" and several are much worn; the ends of retarders wasted slightly at firebox end and the brickwork has drawn off the plates in parts and burnt hollow in places.

There are slight leaks in Nos. 2, 3, 5, 6, 7 and 8 boilers as under:—

No. 2 Boiler.—One rivet in doubling plate at bottom of back end plate of shell.

No. 3 Boiler.—In center combustion chamber, about 6 inch of caulking and stud for securing smoke-box on port side leaking.

No. 5 Boiler.—Bottom palm stay nut at back of boiler.

No. 6 Boiler.—Nuts of palm stays, 2 No. at back of boiler.

No. 7 Boiler.—Palm stay nut at back of boiler.

No. 8 Boiler.—Center furnace saddle seam, about 4 inches of caulking and butt joint of shell at front starboard wing.

There are no leaky tubes in any of the boilers, and the above leaks mentioned are very slight.

The ferrules and retarders are being cleaned by ship's staff, defective ferrules renewed, retarders replaced, and the brickwork and leaks are also being made good.

Hyacinth.

The whole of the eighteen boilers with economizers have been examined externally, whilst the generating elements, feed distributing box, sediment boxes, and steam collector of No. 10 boiler have been opened out and examined internally as well, and doors removed from lower tubes of Nos. 11, 16 and 17 boilers.

A tabulated statement showing the result of the examination is enclosed.

J. T. CORNER, *Chief Engineer.*

W. WILSON,
For Admiral Superintendent.
27th July 1901.

No. 10 Boiler.

The lower fusible plugs were out of Nos. 1, 2 and 8 elements, and in No. 9 element the plugs were out both top and bottom.

No. 9 element; the tubes from No. 5 to No. 14 were bulged in parts from $\frac{1}{32}$ inch to $\frac{3}{16}$ inch. No. 9 wing tube had burst, with an opening 8 inches by 3 inches, the four lower tubes were apparently correct, and the four top tubes were sagged from $\frac{1}{8}$ to $\frac{1}{4}$ of an inch. Very little deposit was in the tubes of this element; in the upper tubes it was in the form of thin, hard scale.

Feed-distributing box had considerable amount of loose scale in it, more especially towards center of box; deposit on the lower tubes was slight, the tubes at water line and above had a hard scale on them in places of about $\frac{1}{32}$ inch in thickness.

The sediment boxes at the bottom were covered with brown, muddy, deposit and scale, especially the starboard one.

In the bottom junction box of No. 3 element hand hole door was found with the bolt in door projecting through the nipple in the feed-distributing box.

Ship's staff removed defective element and replaced it with spare one, cleaned tubes and tested boiler, on completion, to 410 pounds per square inch, this water test being satisfactory.

In accordance with the Controller of the Navy's telegram of the 23d inst., the vertical tubes over and under the burst tube and the burst tube itself have been cut up for inspection, and they are found to have very little deposit on them, and, apart from the bulging above referred to, are in good condition. The bulging of the upper tubes and the sagging of the lower tubes in this boiler, together with slight thinning in the burst tube, is considered to be indications of overheating at some time, due either to imperfect circulation or shortness of water in this boiler, the scale found being insufficient to account for overheating.

ECONOMIZERS.

No. of boiler.	No. of junction box doors leaking.	Nos. of elements.	Extent of leak.
1	1	8	Slight.
3	1	6	Slight.
7	3	1, 3, 5	Slight.
8	4	2, 3, 6, 9	Slight.
9	3	3, 7, 9	Slight.
10	4	1, 4, 9	Slight.
11	2	1, 7	Slight.
12	3	3, 4, 7	Slight.
13	9	1, 2, 3, 4, 6, 7, 8, 9	Slight.
14	7	1, 3, 4, 6, 7, 8, 9	Slight.
16	5	3, 5, 6, 7, 8	Slight.
17	11	1, 2, 3, 6, 7, 8, 9	Slight.
18	7	3, 4, 5, 6, 7, 8, 9	Slight.

HYACINTH-MINERVA.

Upon the termination of the recent combined maneuvers of the British fleets there was another impromptu trial between the *Hyacinth* and the *Minerva* during which the last named vessel overhauled and finally ran away from her rival. During the run one of the *Hyacinth's* boilers primed so badly as to render it necessary to haul fires from the furnaces, besides which there was again an excessive and unaccountable loss of feed water, over 50 tons being lost on the run.

ENGINEERING IN THE BRITISH NAVY.

[From the "Engineer," London.]

There are periodical visitations of an engineering character which occupy the public mind, due chiefly to the prominence given to the matter for the time being in the House of Commons and the press. Such was the case some fifteen years ago, when the proposal to substitute the triple-expansion for the compound engine then in vogue was submitted. To-day the problem of the water-tube boiler is the theme that is attracting the attention, not only of professional engineers, but of that great multitude who

read the daily papers. When it is considered what vast strides in importance machinery has taken within the last few years, whether it be in the manufacture of bicycles, agricultural machinery or marine engines, it will be readily understood how enlarged are the ranks of engineers in all the innumerable pursuits classified under this heading. But it must not be supposed that because an engineer does not happen to work on one particular kind of machinery that he is ignorant of that machinery. Sir Joseph Whitworth once remarked that practice varies, but principles are eternal. Little wonder, then, is it that the subject of naval machinery and boilers is receiving so much attention; and that the majority of the public are now not misled by the articles which appear frequently in our morning and evening papers, many of them purporting to be written by "naval experts," which show lamentable lack of knowledge on the part of the writers. The title "naval expert" is somewhat analogous to that of professor, as used by palmists, quack doctors, and kindred gentlemen, inasmuch as it is self-conferred. The object of this article will be to present to its readers the true position of machinery and those employed in working and tending it on board our men-of-war.

To fully appreciate the condition of things to-day we must go back to the past a little. About 1840 the Admiralty decided on introducing steam into the navy, purely as an auxiliary to sail; and this view of its utility was held by the Board of Admiralty till about twenty years ago, when some ships were built without any sails whatever. Naturally, as steam was of such minor importance, the men in charge of it held no position on board ship; and this state of affairs remained constant for years, in spite of the growth of machinery in every succeeding vessel, and now, even when everything on board a man-of-war is done by engines, the old conditions prevail to a very great extent. It is impossible for anybody to read the history of steam in the British navy without being struck by the opposition with which it has always been met by the Admiralty and the executive officer. It has been, and still is, a question of keeping the whole department subordinate, cutting the weight of machinery down to dangerous limits,

and at the same time exacting the maximum amount of work from it, while the engineers in every ship in the navy are handicapped by the interference of the executive officers. The amount of this interference varies with the ship, but in all it exists. As proof that the Admiralty insist on the executive officer always having control they appointed an admiral president of the committee on water-tubes boilers, with a commander as one of the secretaries, although I can state that neither of these officers would have previously been able to have distinguished between the various types of boilers on which they were going to report.

This cutting down of all concerning the machinery, due to the prejudice and ignorance of the subject of the Board of Admiralty, which is another name for four admirals, has led to the adoption of machinery which every engineer knows is most untrustworthy. The point urged is that weight and space are of primary importance in a ship of war, whereas in merchant vessels there is no such limitation. This is drilled into the head of the young naval engineer as soon as he enters college, and is repeated in all textbooks and papers bearing on the subject. Though I have searched and inquired, I have never yet found out why. Surely a private ship owner is as anxious to save space for his passengers and cargo, and thus save initial cost and subsequent dock dues, etc., as an admiralty naval architect is for his guns and stores. But this desire for lightness and compactness utterly vanishes when relating to matters connected with the ship's hull, especially if it concerns the senior executive officers or affects the ship's appearance. Anybody who, with any mechanical knowledge, has ever looked at such fittings as dead lights for scuttles, brass handrails, brackets for electric lamps, clips for water-tight doors, etc., will readily appreciate the truth of the foregoing remarks. On one occasion, about six years ago, when the channel squadron visited the northeast ports, a mechanical engineer from Leeds was looking over one of the battleships, and asked what a certain valve was for, and on being told that it was for ventilation purposes, remarked that it was strong enough to stand a pressure of 1,000 pounds per square inch. The brass name plate fastened to each bulkhead to designate its number contain twice as much metal

as the bearings of some of the most important auxiliary engines in the ship, the breakdown of which would mean the crippling of the vessel in speed. The natural question is: Why does such a state of things exist? The answer is not difficult. The Admiralty, that is the elderly gentlemen who control naval affairs, have been in ships—most of them sailing vessels—all their lives, and to a certain extent understand something of the requirements of the shipbuilder. The naval architects are civilians, with a gentleman at the head of their affairs who occupies the dual position of chief naval architect and assistant comptroller of the navy. Consequently his voice carries weight with the Board of Admiralty, and it would be monstrous to expect him to attend to the needs of another department which would frequently involve the curtailing of his own requirements. The first thing is to produce a ship on paper, of a certain displacement, carrying so many guns, so many men, and with a given trial-trip speed. This latter fallacy will be referred to later.

Now turn to the engineer-in-chief of the navy. He is always a naval man, is under the naval discipline act, has no seat on the Board of Admiralty, and is given by the ship designer so much space in which to place machinery capable of driving the ship at a given speed. The weight he is allowed is likewise fixed. Further, if he does not meet the wishes of the board he can be sent to sea at any time. Contrast this with the position of the chief engineer of a private shipbuilding concern. Here he takes what space and weight he requires to get the required speed, and the ship designer utilizes the remainder for passenger accommodation, cargo, etc. Of course there must be frequently concessions granted on either side; but in the navy they are all one way. The consequences are the introduction into ships of war of very light engines, running at abnormal speeds, which require constant human supervision whilst under way and continual repair when stopped, due to the excessive wear and tear inseparable from the design. The private ship owners know full well that if they were to supply their ships with the same kind of engines mail contracts would soon be lost, besides passengers fighting shy of untrustworthy vessels. But your naval expert

will say, "You cannot compare men-of-war and merchant ships." Unhappily you cannot; but the reason why you should not be able to do so is not so apparent. A fleet engineer of the Royal Navy, to whom I once spoke about the lack of space in the engine rooms of a battleship then building on the Clyde, which this gentleman was superintending, remarked, "The old story, trying to put a quart measure into a pint pot."

Another accepted axiom is that the engines of all ships of war must be below the water line, because, as a shot only penetrates a few inches under water and then ricochets, the machinery is protected from the enemy's fire. Consequently, as the engines are so low, the speed has to be increased to obtain the required horsepower, and the wear and tear of all working surfaces is greatly augmented with the corresponding liability to failure. Taken roughly, the number of revolutions in a man-of-war in a given time is about one and a half times that of an Atlantic liner for the same speed. No effort is made to decrease this speed of engine by increasing the height; in fact, on the contrary, in modern ships the evil is aggravated. No supporter, however staunch to the Admiralty's present policy, could claim that hot bearings and big defect lists are uncommon in recent vessels. There is apparently no reason why vertical side armor should not be carried higher than at present round the top of the engines, when the risk of its penetration by an enemy's fire would be small as compared to the chances of breakdown or inability to keep the designed speed and probable capture. John Stuart Mill says that if you start with a wrong premise all your subsequent deductions will be wrong. So with the Admiralty. Then try to overcome inherent defects by improvement in mechanical details.

Although the Admiralty fixes the principal dimensions and proportions of all the machinery for the Navy, they very wisely leave it to the ingenuity of the private manufacturers of engines to carry their ideas into effect. It is not too much to say that nearly all the improvements in naval machinery have been suggested by the great outside engineers who execute Admiralty work. The only drawback to the system is that the public is

misled by the results, not knowing how they are obtained. I refer to the trials of engines and boilers which are duly chronicled in the press with much pride. Take, as an example, a battleship which has just recently completed her trials. Besides about forty skilled men in the employ of the contractors, most of whom had previously been engaged putting the engines into the ship, and were, consequently, acquainted with them, there were lent for the trials thirty-seven chief stokers; sixteen leading stokers, first-class; five leading stokers, second class; and one hundred and ninety-nine stokers. Beyond this there were contractors' managers, Admiralty representatives, and an army of men from the dockyard. Now contrast this with her complement when commissioned and ready for action—six engineers, nine artificers, six chief stokers, twelve leading stokers, first-class; six leading stokers, second-class; and one hundred and eight stokers; quite fifty of the latter being second-class men, who do not know a boiler from a condenser. So with one assistant engineer on watch, together with two artificers, one chief stoker, three leading stokers, and about thirty stokers, the same results are expected as on the trials. No modern ship can possibly steam at anything like her full speed without considerable assistance from the upper deck, when the "handy man" trims the coal for the stokers to throw on the fires. But this is all very well in peace time, when the only object is to get a satisfactory trial report to the Admiralty; but what is going to happen in war time, when the "handy man" is standing behind his gun, and is not available for coal trimming?

Another proof, if proof were needed, of the esteem in which the Admiralty holds engineering, is to be found in the destroyers employed in instructional work. These boats, which are of the flimsiest construction, run for three weeks out of the month, one week of which is at full speed. Into these vessels, lately, have been introduced artificer engineers, in spite of every conceivable article on board being in the engineer's charge, and the engines developing between 4,000 and 5,000 H.P. This is about equivalent to the power of most of the liners running to Australia and the east, which usually carry a complement of six or

seven engineers. Thus, in the Navy one man does the work that six do outside, and although artificer engineers are most excellent men, they cannot be expected to do the work of highly trained and scientific engineers. It is so throughout the service. The engine rooms are starved, but a reference to the Navy list will prove that, in all cases, the upper deck officers are fully represented.

The average man, when he thinks of the engineer, imagines him only to be a person who propels the ship through the water. Here is a short list of his other responsibilities: Lighting the ship with electricity; the care and maintenance of all gun machinery, which in a battleship is not inconsiderable; the manufacture of fresh from salt water, and in hot weather the icing of the same; the maintenance of all torpedoes, with repairs after they have been fired by the "handy men," together with all the air-compressing machinery for charging them; steering machinery, capstan machinery, the skin of the ship, and, in short, a list that would nearly fill a page. The engineer bears the same relationship to the executive and the other officers that the watchmaker does to the man who winds up his watch every night. As soon as it gets out of order take it back to the watchmaker; the only difference being that the watchmaker does his work unmolested by outside interference.

To revert now to the machinery. The boilers are the heart to a steamer. It is they that supply the steam which drives the engines. Until quite recently—1894—the Admiralty practice was to fit the cylindrical fire-tube or Scotch boiler working at a pressure of 155 pounds per square inch. Long before this there were some merchant vessels working at 200 pounds and above with the same class of boilers, and why the Admiralty never for years increased this pressure is a mystery. The answer is again as before—weight. The thickness of all parts of a boiler has naturally to be increased with the pressure, which adds to the weight. This is more pronounced in a Scotch boiler than in one of the water-tube species. Water-tube boilers are divided into two classes. First we have the small-tube variety, with straight or bent tubes of about an inch in diameter, connecting water

pockets at the bottom to a steam drum at the top. This type has been fitted in the Royal Navy to all destroyers, and to many gunboats and small cruisers. The Yarrow, Thornycroft, Reed and Normand are perhaps the best known, and the principal difference in them is the curvature of the tubes. Then there is the big-tube type, with tubes of from 3 inches to 4½ inches in diameter, connecting a bottom water tube with a steam drum at the top, but the tubes in this case lying in a horizontal plane. This type includes the Belleville, Niclausse and Babcock & Wilcox, and is intended to serve in big vessels and for long periods of steaming.

The small-tube boiler first came to life about twenty-five years ago, owing to the demand then for higher speeds in torpedo boats. It is a very light boiler, which can be forced to an extent that other steam generators cannot. It has practically enabled the modern torpedo-boat destroyers to attain their great speeds; but the life of the boiler is very short, the repairs required very great, and the skill in handling very considerable. These sacrifices are only what can be expected from a boiler designed to drive such frail craft as destroyers. Their average life is about two or three years; but there are several new boats lying in the dockyard, reserves that have had to have their boilers retubed in spite of only having recently been built, and never having steamed except on their trials. This is due to the decay that goes on inside the tube whilst the boilers are idle, and as the tubes are very thin, they, consequently, cannot afford to lose very much in thickness. Taken altogether they are costly and untrustworthy boilers; but they enable ships to get very high trial-trip speeds, and afterwards to find plenty of employment for the dockyards. These boilers have been fitted in many large vessels in foreign navies, but have not been considered sufficiently good for this purpose by the British Admiralty.

Turning now to the big-tube type—which is the boiler that has of late been the subject of so much controversy—we find that it has been universally adopted by the Admiralty for all ships designed since 1894, excepting the small vessels with "express" boilers, referred to earlier in this article. The history of these

boilers in the British navy is briefly this: In 1892 the Admiralty, always on the outlook to cut down weight, fitted eight Belleville boilers to the torpedo gunboat *Sharpshooter*, which had previously given a lot of trouble, not so much with her boilers, which were of the modified locomotive type, as with her engines, which were so light as to be unequal to their work. These Belleville boilers worked at 150 pounds per square inch. After a series of trials at low powers in the channel, which were kept very secret, the Admiralty ordered this type of boiler for the *Terrible* and *Powerful*, but increased the pressure to 260 pounds. Finding the coal consumption of these French innovations very high, the Admiralty hit on the plan of fitting a feed-water heater on top of the boilers to catch some of the escaping gases, which they called economizers. These were first fitted to the *Diadem* in 1895, in which the pressure had been increased to 300 pounds per square inch. Everybody who knows anything about physics or engineering is aware of the considerable economy effected by using high-pressure steam and expanding it down to a low pressure. But it never seemed to occur to the engineering officials at the Admiralty that the major part of a man-of-war's time is spent in harbor, where the only engines needed are a dynamo for illuminating purposes, a circulating and air-pump engine to condense and remove the exhaust steam, and a bilge pump. These machines require probably about 30 pounds of steam to drive them, with the exception of the dynamo, which needs about 80 pounds. Consequently, where is the gain in using 300 pounds if you only require 80 pounds? The Admiralty was forced to seek a subterfuge, and to employ the high pressure and exhaust the steam at a correspondingly high rate. For example, instead of using 80 pounds to drive the dynamo and exhausting at no pressure, they use 140 pounds and exhaust at 60 pounds. The wear and tear of all parts is considerably increased, and it is admitted by all who have sailed with this clumsy arrangement that the leakage from joints, not to speak of the extra work on the engineering staff, far outstrip any theoretical gain. So in two of the points which the Admiralty prided themselves on benefitting by the introduction of water-tube boilers, namely, coal consump-

tion, which is a very important factor in the question of weight of machinery, and economy of steam, experience has not fulfilled their anticipations.

Like their brethren of the small-tube type, these boilers are very short lived—the Engineer-in-Chief of the Navy considers about six years; but none of them in the English service have as yet lasted so long. A number of sloops have recently been built for service in foreign waters, far removed from any of the dock yards where repairs can be effected, yet the Admiralty, pledged to its policy, felt bound to fit water-tube boilers to these vessels, the maximum speed of which is only 13½ knots, and for this they require 300 pounds pressure and 180 revolutions. Sixty revolutions and 100 pounds pressure a few years ago would have sufficed to obtain this speed, and the ships would have lasted double the time and cost much less in repair and upkeep.

In spite of all the talk of "improved" machinery of modern vessels, speeds have remained nearly constant in big ships, and particularly cruisers, for the last ten years. There are few naval officers who will not agree that in a long run the *Edgars* and *Blenheims* of ten years ago would not be last in a race with the *Diadems* and *Cressys*, and would be much more certain of finishing than their modern rivals. Improvement with regard to naval machinery means increased complexity and trouble to those who have to work it.

Last summer the then First Lord of the Admiralty appointed a committee of one naval and four private engineers to consider the question of water-tube boilers for ships of war. This policy was dictated by frequent breakdowns of ships fitted with them, and the comments of the press and public on the matter. But the committee was not appointed till all modern ships had been so fitted, representing some £50,000,000 sterling. However, better late than never. They have recently published an *ad interim* report in which water-tube boilers are advocated, but the Belleville type condemned. As the report is only *ad interim*, and, as the committee are still seeking evidence with regard to which type of boiler is the best for naval purposes, it is only

proposed to investigate the reasons advanced for advocating the adoption of water-tube boilers at all. The reasons given are: (a) Rapidity of raising steam and of increasing the number of boilers at work; (b) reduction to a minimum of danger to the ship from damage to boilers from shot or shell; (c) possibility of removing damaged boilers and replacing them by new boilers in a very short time, and without opening up the decks or removing fixtures of the hull.

The first reason (a) of quick steam raising is one which has all along been urged by water-tube boiler enthusiasts to be one of their strong characteristics. But the importance of this matter may be easily exaggerated. A Belleville boiler takes about two hours to get steam from cold water, and a Scotch about four. These times may be considerably reduced if necessary, by forcing the fires; but the penalty is leaky joints, together with collapse of brickwork in the Belleville, due to the "bumping" of the water when on the point of ebullition. No more damage is done to a Scotch than to a water-tube boiler by forcing it, and on one occasion of emergency I raised steam from cold water to 100 pounds in three hours in the largest class of double-ended boilers fitted in the Navy without any visible harm. The trials of the *Minerva* and *Highflyer* proved the truth of these remarks. Granted, then, that the water-tube boilers can raise steam in half an hour in an extreme case, what is the good of having steam in your boiler if you cannot move your engines? The large engines now fitted to big ships take at least two hours warming up before they are ready to move; otherwise there is grave risk of breaking something, due to water forming in the cylinders. But what ship in war time is going to be lying with her boilers not alight? and if the fires are banked then the Scotch has just as much advantage as any water-tube boiler.

The second reason (b) appears somewhat problematical. It means that a ship being supplied with a great number of water-tube boilers, the loss of one or two of these small units makes no difference to the speed of the ship compared with the loss of one large Scotch boiler, of which there are only a few fitted in the ship. But all boilers in the Navy are below the water line,

and placed beneath an armored deck, and should shot or shell get into these regions it would not very much matter what class of boilers is supplied. No man would care to stop, even if he could, after the bursting of one water-tube boiler to see whether the remainder went or not, and as everything depends upon human attention, this feature of the water-tube boiler does not appear of so much importance.

The third reason (c) resolves itself into a question of expense. If a boiler is sufficiently damaged to require replacing by a new one, it will become too big a job for the ship's staff, and will have to be undertaken by the dock yards or private contractors. This is true of all boilers, and as regards the removal of fixtures of the hull, it depends on what extent of damage has been done to the boiler, because it is hard to imagine a case in which a boiler is damaged without some of the surrounding pipes, valves, etc., also being wrecked.

Taken altogether, the reasons given for adopting water-tube boilers are open to discussion, inasmuch as no experience is forthcoming up to the present with regard to the behavior of these boilers in action, and consequently all questions of this character must be theoretical till practical experience is gained. The objections urged against the Belleville boiler by the committee appear, with one or two exceptions, to apply equally to all water-tube boilers, and not one particular example more than another. Any boiler containing only a small quantity of water, and generating steam at very high pressures, is bound to be very sudden in all its actions, and to require considerable attention, which is much increased when the machinery that it supplies is being frequently stopped, started and worked, sometimes slowly and the next minute at maximum speed. This is the lot of naval engines, and to overcome these difficulties automatic gear is fitted to the boilers to control the various actions, and it is frequently difficult to decide which is the more troublesome—the automatic gear or the varying conditions of the boiler. In the channel squadron, where maneuvering is of daily occurrence at sea, the increase of power is often as much as 4,000 H.P. at one leap. All the battleships are supplied with fairly substantial

machinery and Scotch boilers, and in spite of their most trying work seldom, if ever, fail. Indeed, the total defects of the eight battleships in a year is not equivalent to those of two of the cruisers fitted with water-tube boilers. This latter feature would be of vital importance in war time. Without trustworthy machinery a warship is a poor substitute for a floating fortress.

THE FUEL ECONOMY OF THE BRITISH "B FLEET" IN THE NAVAL MANEUVERS OF 1901.

The naval maneuvers which recently took place, have provided many writers with an interesting theme for discussion and criticism. Articles have appeared in newspapers and magazines in which these operations have been carefully reviewed, and an attempt made to draw therefrom some useful lessons. In nearly every case, however, the writer has approached the subject from a single standpoint, viz: that of naval tactics; whilst the engineering aspect of the maneuvers has not received the attention which its importance undoubtedly warrants. In studying the matter from this point of view one finds there is a very large field, offering many points of interest to the naval student and to the engineer. The question, for instance, of the coal consumption of the various ships is one of first-rate importance. The accompanying tables have been compiled to throw some light upon this point. These tables show the amounts of coal burnt by each of the twelve battleships which compose the "B Fleet." Other data are also included which enable one to compare the relative fuel economies and steaming capabilities of the various vessels. The special value of these figures lies in the fact that they were obtained under the conditions which would rule in actual warfare, and they represent the actual efficiencies of these ships at the present moment. The battleships of the "B Fleet" are old vessels, except the *Revenge*, the flagship of the fleet. Notwithstanding the fact, however, that they are growing somewhat obsolete according to modern ideas, yet they are still of great value and importance; for it will be upon these vessels composing a reserve fleet, that we shall have to rely as our first

TABLE I.—PARTICULARS AS TO THE COAL CONSUMPTION OF THE "B FLEET" BATTLESHIPS DURING THE PRELIMINARY CRUISE.

Name of ship.	22d July. Coal used.			23d July. Coal used.			24th July. Coal used.			25th July. Coal used.			26th July. Coal used.			27th July. Coal used.			28th July. Coal used.		
	Main engines.	Auxiliary purposes.	Total.	Main engines.	Auxiliary purposes.	Total.	Main engines.	Auxiliary purposes.	Total.	Main engines.	Auxiliary purposes.	Total.	Main engines.	Auxiliary purposes.	Total.	Main engines.	Auxiliary purposes.	Total.	Main engines.	Auxiliary purposes.	Total.
H. M. S.	tons. cwts.	tons. cwts.	tons. cwts.	tons. cwts.	tons. cwts.	tons. cwts.	tons. cwts.	tons. cwts.	tons. cwts.	tons. cwts.	tons. cwts.	tons. cwts.	tons. cwts.	tons. cwts.	tons. cwts.	tons. cwts.	tons. cwts.	tons. cwts.	tons. cwts.	tons. cwts.	tons. cwts.
Revenge	29 0	9 0	38 0	25 0	12 0	37 0	27 0	13 0	40 0	29 0	13 0	42 0	26 0	13 0	39 0	39 0	3 9	42 9	75 0	13 0	88 0
Trafalgar	22 12	8 12	31 4	17 7	14 10	31 17	23 10	12 19	36 9	29 3	5 6	34 9	20 7	16 9	36 16	26 17	17 6	44 3	61 10	6 8	67 18
Nile	20 0	12 0	32 0	18 0	12 0	30 0	18 0	13 0	31 0	29 0	5 0	34 0	20 0	19 0	39 0	27 0	13 0	40 0	43 0	22 0	65 0
Camperdown	30 0	7 18	37 18	23 14	7 11	31 5	29 19	7 8	37 7	30 10	8 0	38 10	27 8	11 2	38 10	31 27	10 10	42 7	81 9	10 11	92 0
Benbow	20 12	6 12	27 4	20 10	14 13	35 3	22 11	9 9	32 0	29 4	7 14	36 18	17 18	7 14	25 12	30 14	9 6	40 0	69 18	8 6	78 4
Dreadnought	31 10	10 10	42 0	31 6	6 14	38 0	30 0	12 3	42 3	29 7	15 13	45 0	31 14	11 6	43 0	42 2	8 8	50 10	82 16	8 14	91 10
Sans pareil	25 15	... ...	... ...	19 10	10 10	30 0	25 0	13 10	38 10	21 0	13 0	34 0	24 0	12 0	36 0	30 2	13 15	43 17	50 0	13 0	63 0
Howe	28 10	8 18	37 8	18 15	10 17	29 12	26 4	11 11	37 15	25 7	10 6	35 13	23 15	10 7	34 2	30 0	9 9	39 9	70 8	9 16	80 4
Colossus	16 0	5 11	21 11	15 15	6 3	21 18	21 0	7 0	28 0	21 16	6 13	28 9	21 14	6 18	28 12	28 6	6 15	35 1	54 18	6 14	61 12
Anson	27 2	8 12	35 14	22 0	10 0	32 0	22 17	14 19	37 16	26 10	10 4	36 14	24 16	10 16	35 12	31 10	10 6	41 16	79 14	10 18	90 12
Collingwood	24 18	6 16	31 14	20 10	16 6	36 16	24 8	9 10	33 18	26 16	9 14	36 10	21 2	9 16	30 18	31 18	10 16	42 14	65 0	9 16	74 16
Edinburgh	... ...	... ...	... ...	... ...	... ...	... ...	37 0	20 0	57 0	44 10	... ...	... ...	21 2	20 2	41 4	29 2	10 2	49 4	85 17	8 12	94 9

line of defence against invasion in the event of a war. It seems very probable that upon the outbreak of hostilities the Channel fleet would be sent to reinforce the Mediterranean fleet, leaving our coasts and shipping to the protection of the reserve fleet. Yet another use for such a fleet is possible. If the belligerents were well matched, and the struggle a fierce and vigorously sustained one, it is quite conceivable that the vessels on either side might eventually become mostly disabled or destroyed. If such a state of things were reached, our reserve fleet would come along and sweep the seas.

In discussing the question of coal consumption as regards the "B" or "defending fleet," the Navy maneuvers may be divided into three parts: (a) the preliminary cruise; (b) the dash southwards; (c) the search for the enemy.

(a.) The particulars as to the amounts of coal consumed during the preliminary cruise are shown in Table I. The conditions of this cruise were just such as might actually occur prior to a war. A declaration of war being expected, it was necessary for tactical reasons to reach a certain latitude before hostilities commenced; also the men had to be drilled and the ships exercised at sea in various formations. At the same time everything possible had to be done to reduce the expenditure of fuel to a minimum, so that the bunkers should be depleted as little as possible before the struggle began. Stated briefly, then, a certain distance had to be traversed, a certain time spent in cruising, and the least possible amount of coal burnt in accomplishing these two objects. These conditions were satisfied in practice by adopting an average speed of 8 knots, and by putting into harbor each night except on one occasion. For the majority of the ships 8 knots was probably about the most economical speed. An inspection of Table I seems to show that the *Nile*, *Revenge* and *Colossus* were the most economical vessels, having regard to their differences in tonnage and horsepower. On three days the *Edinburgh* burnt very large quantities, which is all the more remarkable as her sister ship, the *Colossus*, on most days used the smallest amount of any vessel in the fleet. Also the *Trafalgar* and *Nile*,

two other sister ships, gave practically the same results throughout.

(b.) The second part of the maneuvers consisted of a hurried rush from the latitude of Leith to Portland, and the circumstances attending this dash southwards were as follows. War had been declared, and the Admiral's first object was to fill up with coal. The nearest coaling station being Portland, the fleet had to make for this destination with the utmost speed possible. As in the previous cruise the prime necessity had been economy, so in this one the chief essential was speed. A speed of 11 knots was maintained during this trip. Something like 12, or even 13 knots might have been made on this run, but the risk of breakdowns would have been largely increased thereby, and it was, perhaps, due to this consideration that the lower speed was selected. Owing to variations in revolutions and to other causes it was not found possible to arrange the figures in this case as in the former one.

TABLE II.—PARTICULARS OF COAL CONSUMPTION OF THE "B FLEET" BATTLESHIPS DURING THE RUN SOUTH.*

Name of ship.	Coal used during a period of 10 hours.					
	Main engines.		Auxiliary purposes.		Total.	
H. M. S.	*tons.*	*cwts.*	*tons.*	*cwts.*	*tons.*	*cwts.*
Revenge	63	9	10	0	73	0
Trafalgar	49	9	13	0	62	9
Nile	40	0	12	0	52	0
Camperdown	63	6	12	6	75	12
Benbow	52	12	8	0	60	12
Dreadnought	60	10	8	10	69	0
Sanspareil	40	0	13	0	53	0
Howe	56	6	10	3	66	9
Colossus	43	3	6	6	49	9
Anson	58	12	10	0	68	12
Collingwood	55	5	9	10	64	15
Edinburgh	62	10	15	18	78	8

* EDITORIAL NOTE.—Probably coal for 24 hours on the basis of coal used for 10 hours.

Table II shows the coal expenditure for each ship over a period of ten hours during this cruise. The *Camperdown* and *Edinburgh* appear to have given rather poor results, whilst the *Nile* and *Colossus* once again head the list for economical steaming.

TABLE III.—PARTICULARS OF THE COAL CONSUMPTION OF THE "B FLEET" BATTLESHIPS DURING THE SEARCH FOR THE ENEMY.

Name of ship.	31st July. Coal used.			1st August. Coal used.			2d August. Coal used.			3d August. Coal used.			4th August. Coal used.		
	Main engines.	Auxily. purposes.	Total.	Main engines.	Auxily. purposes.	Total.	Main engines.	Auxily. purposes.	Total.	Main engines.	Auxily. purposes.	Total.	Main engines.	Auxily. purposes.	Total.
	tons. cwt	tons. cwt	tons. cwt	tons. cwt	tons. cwt	tons cwt	tons cwt	tons. cwt	tons. cwt	tons. cwt	tons. cwt	tons. cwt	tons. cwt	tons. cwt	tons. cwt
H. M. S. *Revenge*	46 0	10 0	56 0	39 10	8 10	48 0	31 0	9 0	40 0	48 0	9 0	57 0	51 0	9 0	60 0
Trafalgar	49 9	13 0	62 9	30 0	12 12	42 12	28 11	10 5	38 16	43 0	15 10	58 10	46 12	6 1	52 13
Nile	40 0	12 0	52 0	33 0	13 0	46 0	18 0	11 0	29 0	33 0	13 0	46 0	40 0	12 0	52 0
Camperdown	63 6	12 6	75 12	42 9	9 13	52 2	34 3	11 14	45 17	47 9	9 17	57 6	50 9	10 0	60 9
Benbow	52 12	8 0	60 12	38 16	6 16	45 12	27 17	7 15	35 12	43 0	8 10	51 10	43 4	11 1	54 5
Dreadnought	60 10	8 10	69 0	46 9	9 3	55 12	31 6	10 10	41 16	53 12	9 18	63 10	30 14	8 18	59 12
Sanspareil	40 0	13 0	53 0	34 8	14 0	48 14	29 0	13 0	42 0	38 0	13 11	51 11	42 16	13 4	56 0
Howe	56 6	10 3	66 9	35 15	20 17	56 12	28 2	10 6	38 8	46 16	9 8	56 4	42 2	9 16	51 18
Colossus	43 3	6 6	49 9	36 14	5 16	42 10	27 7	8 8	35 15	37 6	5 8	43 4	40 18	7 4	48 2
Anson	58 12	10 0	68 12	44 14	13 10	58 4	31 12	11 18	43 10	52 6	11 8	63 14	47 13	11 1	58 14
Collingwood	55 5	9 10	64 15	44 16	14 2	58 18	29 6	10 12	39 18	39 18	10 12	50 10	46 8	10 6	56 14
Edinburgh	62 10	15 18	78 8	49 16	9 4	59 °0	34 16	9 1	43 17	39 19	6 19	46 18	52 8	9 13	62 1

TABLE IV.—CONTAINING FURTHER PARTICULARS AND DEDUCTIONS FROM THE DATA OF THE OTHER TABLES.

Name of ship.	Tonnage.	I.H.P.	Coal that can be carried in bunkers.	Distance that ship can steam with one ton of coal.				Total distance ship can steam starting with full bunkers.			
				At 7 knots.	At 8 knots.	At 9 knots.	At 11 knots.	At 7 knots.	At 8 knots.	At 9 knots.	At 11 knots.
	tons.		tons.	knots.	knots.	knots.	knots.	knots.	knots.	knots.	knots.
H. M. S. *Revenge*	14,150	13,000	1,800	3.4	2.0	2.8	3.0	6,120	3,600	5,040	5,400
Trafalgar	11,940	12,000	1,200	3.7	2.7	3.7	3.9	4,440	3,240	4,440	4,320
Nile	11,940	12,000	1,200	3.8	2.9	4.1	4.7	4,560	3,480	4,920	5,640
Camperdown	10,600	11,500	1,200	3.2	2.1	3.0	3.0	3,840	2,520	3,600	3,600
Benbow	10,600	11,500	1,200	4.0	2.7	3.5	3.7	4,800	3,240	4,200	4,440
Dreadnought	10,820	6,500	1,200	3.1	1.7	2.0	3.1	3,720	2,040	3,120	3,720
Sanspareil	10,470	14,000	1,200	4.2	2.4	3.4	4.7	5,040	2,880	4,480	5,640
Howe	10,300	11,500	1,200	3.8	2.3	3.3	3.6	4,560	2,760	3,960	4,320
Colossus	9,420	5,500	970	4.4	3.4	3.7	4.4	4,268	3,298	3,589	4,268
Anson	10,600	11,500	1,200	3.7	2.2	3.4	3.6	4,440	2,640	4,080	4,320
Collingwood	9,500	9,500	1,200	3.9	2.4	3.3	3.4	4,680	2,880	3,960	4,480
Edinburgh	9,420	5,500	970	2.8	...	2.8	3.0	2,716	...	2,716	2,910

(c.) The concluding phase of the operations extended over a period of six days, and consisted of a search for the enemy up and down the channel, ending at last in the meeting of the hostile fleets, and a great battleship action off the Lizard. The coal consumption particulars are arranged in Table III. The speed maintained varies from eight to ten knots. The figures contained in this table show the *Edinburgh* to have given better results than before, but otherwise there is nothing which calls for any special comment.

In Table IV certain deductions have been worked out from the data of the previous tables, and from the general results obtained from the maneuvers. With regard to the total distances each vessel would be capable of steaming, it must be noted that no allowance has here been made for coal burnt for auxiliary purposes. It is a relatively small, but widely varying quantity in different ships. In the case of an emergency it could probably be much reduced by stopping the electric light. If some such steps were not taken, and it were necessary to run the distilling plant, then the distances given in the table would have to be reduced by 20 per cent. or more.—" Marine Engineer," October 1, 1901.

THE *COBRA* DISASTER.

The verdict of the court martial given on Wednesday last will be read with sincere regret by every one—at least everyone who loves England. It will not be supposed that in saying this we regret that the surviving members of the crew of that ill-starred vessel should be acquitted of blame, for that conclusion was never a matter in doubt for a moment. The man who might, under possible contingencies, which did not arise, have been blameworthy went down with his ship, and nothing occurred throughout the disastrous voyage that could reflect blame on him. It is not necessary to say more of a brave seaman who died at his post. The custom of holding a court martial on the survivors of a wrecked vessel is a useful one, even though, as in this case, it is no more than a formality. So long as it is universal, it attaches, in itself, no suspicion of blame to those tried, and there-

fore the facts connected with a wreck can be impartially sifted without the loss of prestige that would accrue if even a *prima facie* case had to be made out against the survivors before they could be brought to trial. Mr. Percey could never have had much anxiety about the issue, and no one can doubt that the verdict is, so far as he and his shipmates are concerned, absolutely logical and just.

The following is the text of the verdict of the court:

"The court, having taken the evidence of Chief Engineer J. J. G. G. Percey, and that of the remainder of the survivors, and having weighed and considered the whole of the evidence before them, find that His Majesty's ship *Cobra* foundered on the morning of the 18th day of September, 1901, while on passage from the Tyne to Portsmouth. The court has come to the conclusion that His Majesty's ship *Cobra* did not touch the ground nor meet with any obstruction, nor was her loss due to any error in navigation, but was due to structural weakness of the ship. The court also find that the *Cobra* was weaker than other destroyers, and in view of that fact it is to be regretted she was purchased into His Majesty's service. The court further finds that no blame is attributable to Chief Engineer J. J. G. G. Percey nor the remaining survivors, and fully acquits them."

The President added that the court desired to express their opinion that the handling of the dinghy after the accident was worthy of all praise, and torpedo coxswain Francis Barnes deserved great credit for the way in which he acted on the trying occasion.

The President then returned Mr. Percey his sword, remarking that he had great pleasure in doing so.

It is in the judgment passed on the vessel herself that there is cause for regret. We are told that the *Cobra* was below the proper standard of strength for destroyers, and should not have been accepted for the Royal Navy. The statement will be greedily seized on by some as a condemnation of the public department which we would fain see the most efficient in the whole range of the Government service, and of a private engineering and shipbuilding establishment of which we have always thought—

and with justice—we have most occasion to be proud. It will be a matter of regret if the impression conveyed by the sweeping terms of the verdict leads to exaggerated feelings of alarm. Our Navy has been so largely successful that a single disaster comes as an unexpected event, and all are apt to measure the force of a calamity by its rarity. It is true the *Cobra* disaster does not stand alone—excepting in its unhappy loss of life—but those other mishaps which have revealed the weakness of destroyers in a less tragic manner are part of the same error. The unparalleled fleet of noble ships that has been built up under the auspices of Sir William White and Sir John Durston, and their respective staffs, has been so uniformly admirable that the country has come to expect perfection as a matter of course. Use has made us callous to the fact that our dockyard-built ships, equally with our contract-built ships, are triumphs of naval architecture and marine engineering which the navies of all the world have copied; but we pay the penalty of pre-eminence, for a disaster in the Royal Navy is more noised abroad than a dozen similar calamities elsewhere. It is, perhaps, because our disciples think they may be subject to the same defect.

The facts concerning the loss of the *Cobra* have been fully canvassed of late, and there is very little in dispute. The vessel was built by Messrs. Armstrong, Whitworth & Co., in order to try the Parsons steam turbine. Mr. Watts has told us that the idea was to frame the design of the vessel so that she would pass Admiralty inspection if the Government wished to purchase her. She was, however, mainly experimental, and was a larger and more highly-powered vessel than any of her class which had up to then been added to the Navy, her length being no less than 223 feet 6 inches. Her machinery, too, came out 30 tons heavier than was anticipated, the total weight being 183 tons. These figures may be compared with those for two former destroyers built at Elswick for the Royal Navy—the *Swordfish* and the *Spitfire*—which were 200 feet long, and had machinery weighing 110 tons. It is worth noting that the extra weight of the *Cobra's* machinery was estimated to give her 60 per cent. more power than there was in the *Swordfish*.

From the evidence given at the court martial it would appear that the scantling of the *Swordfish* was retained for the *Cobra*, but that the latter was made a foot deeper, thus, of course, adding to the strength of the girder formed by the hull. This extra foot of depth was calculated, according to Mr. Pine, the Admiralty constructor who surveyed her before her purchase, to add 17 per cent. to her longitudinal strength. Whatever the intentions of the designers were, however, the Admiralty officials did not take quite the same view, for on being officially surveyed, with a view to purchase, it was reported that the scantling needed strengthening. A large quantity of material was therefore worked into the structure—nearly all, we believe, in the deck construction. We are informed that the amount was 7 tons, but the quantity seems so large for a vessel of this type that one has some difficulty in accepting the statement. In any case the deck proved strong enough, for it did not give way until the lower flange of the girder, the bottom of the ship, was ruptured. As the vessel sank she doubled up, the deck—to use the expression of one of the survivors—folded up like a hinge; whilst the light-ship man who saw the catastrophy spoke of two funnels crashing together as she went down.

The first accounts received, no doubt, were calculated to lead to the impression that the wreck was due to the vessel striking the bottom, and, indeed, the first official report stated that the *Cobra* had gone on the rocks. When the position where the vessel foundered was more clearly defined, it was evident this could not have been the case, as there are no rocks marked in the vicinity, and, indeed, the depth is too great even for the vessel to have touched the sand and shells which here form the shallower spots to which the Dowsing Lightship acts as a warning for much deeper-draught craft. In short, touching the bottom is out of the question. But it is held by some that the *Cobra* struck a wreck, and the damage done to the bottom started a rent which developed into the severance of the whole skin through subsequent wave action. Of course, there is nothing to disprove this theory, but we fear it rests on very slender hypotheses. Unfortunately, too, it does not need any such explan-

ation to account for the collapse of the hull, if we may take the witness of other destroyers.

In the official publication issued by the United States Intelligence Bureau is a statement respecting the destroyer *Seal*, built at Birkenhead for the Royal Navy. In April last, it would appear, this vessel was struck by a heavy sea when cruising in the Bristol Channel. It was thought at first by those below that she was in collision, for the blow was so violent that, in the language of the report, her back was broken, and she was unfit for further service. "Her deck was cracked clean across, admitting daylight to the fireroom, and the side plating was split for 18 inches." The report further states that the trouble is ascribed to "the unsuitability of torpedo-boat destroyers to knock about in weather that causes larger vessels to take shelter."

A more recent case is that of the destroyer *Crane*, built at Jarrow. Within a week or ten days ago, she, according to reports in the newspapers, had to put back to Portsmouth because her deck had buckled badly, and we were further informed that the defect was so serious that the vessel had to be put out of commission for repairs. Yet another case, reported in the press within the last few days, is that of the destroyer *Vulture*, built at Clydebank, which also, it is stated, had to put back to Portsmouth on account of structural defects developed through stress of weather.

If these reports are true—and we need hardly say we shall be only too pleased if we can be allowed to contradict them—there is no getting away from the fact that some of our destroyers, at least, are dangerously weak in their construction. Few, we think, will hold the view expressed by Mr. Parsons, in giving evidence before the court martial, when he said he thought the *Cobra* was intended to be a fair-weather boat; or that destroyers should not be able "to knock about in weather that causes larger vessels to seek shelter." These craft were distinctly intended to accompany the fleet; and craft of this size cannot, if they are to be any good, keep in the neighborhood of a port of refuge. They must be able to take the sea and keep the sea in all weathers.

There is no reason why well-designed and well-built destroyers

should not do so. To design vessels of this importance that are liable to have their backs broken if they meet a wave of their own length would be a piece of foolishness that no competent naval authority has ever contemplated; and certainly the Admiralty would never be justified in asking sailors to venture to sea in such craft. However, the proposition is too far-fetched to be worth discussing, especially as there is no need to contemplate the need for such caution. A thorough overhaul of the destroyers throughout the Navy will, we presume, be undertaken. It is no good blinking the fact that errors have been made or else too much has been taken for granted. These small steel craft have proved themselves so tough at times that an impression has grown up that they can hardly be injured; and though that may be true if they are properly put together, the process is one needing the greatest skill and care, which, it is to be feared, has not always been at command. The necessary calculations will have to be undertaken to discover whether a sufficient margin of strength in the scantling has been left for safety, the data being obtained, not from drawings, but by measurements from the actual vessels. A close inspection must also be made of the whole structure to find whether there are any unexpected places of weakness, due to improper working of material, to uncompensated deck openings, or to bad disposition of parts. For instance, bulkheads should be attached to the hull structure so that the stresses they transmit would be well distributed; and care should be taken that no abrupt and sudden changes of strength occur.

Some of these vessels are reported to have midship cross bunkers in conjunction with wing bunkers. The bulkheads to the latter form an important element of longitudinal strength. It would be interesting to know whether these fore-and-aft bulkheads are continued through the cross bunker or not. The riveting of lightly-plated vessels is a matter upon which a good deal depends. To properly close cold rivets in torpedo boats is a very different matter to the ordinary hot riveting in inch plates. There is no need here to point out the need of close, good riveting to obtain the strength due to friction of parts

pressed hard together. Further, plates that are properly trued before erecting also give most strength to the structure. There is a great deal more than mere appearance to consider in that most difficult art—light plating. All these and a hundred other points must be considered in the construction of torpedo craft. Their design and their building are special branches of the naval architect's profession and the shipbuilder's craft, proficiency in which is only obtained by long study and extended experience.

Mr. Watts stated in his evidence that calculations made showed that the greatest stress on the steel of the *Cobra's* hull could not exceed 9 tons to the square inch. This would, of course, be on the usual assumption that the vessel was on the crest or in the trough of a wave her whole length, but presumably the calculations only referred to static conditions. The steel in this vessel appears to have been of the ordinary type, with a 28 to 30-ton tensile strength—the new high-tensile material which has been applied to some vessels since built not being used. The margin of strength allowed in the *Cobra* would, therefore, appear to be less than that which was considered desirable in some of the earlier craft. It will be remembered that Messrs. Thornycroft & Barnaby, in their now famous paper read five and one-half years ago before the Institution of Civil Engineers,* gave 6.4 tons per square inch as the stress upon the material at the section where the greatest bending moment occurs in one of the earliest destroyers. Probably that may be considered a strength in excess of actual requirements, especially as it contemplated the vessel in a position it might never assume. Still, the circumstances are quite possible; one might say even probable, taking the whole life of the ship. Sir William White, in his "Manual of Naval Architecture," says that with a stress of 8 to 9 tons per square inch for iron, strengthening by additional material becomes necessary, and allows 25 to 30 per cent. greater strength for steel than iron.

It is, however, needless to say that the whole question of longitudinal strength, when one deals with the case of a ship progressing among waves—the actual condition met with—is

* Proceedings of Institution of Civil Engineers, Vol. CXXII, session 1894-5.

one of extreme complexity. Attempts have been made by many competent authorities to deal with the subject, but naval architects, as a rule, do not consider the problem has been solved in a way that gives quantitative results. The accelerating forces due to pitching and scending, and other causes, cannot be estimated with any degree of certainty, and the calculations can only be taken to give comparative data. In the case of the *Cobra* the evidence of the diver who examined the wreck was to the effect that there was a bulge in the plating, and if this were caused by submerged or partly submerged wreckage, the conditions upon which calculations would be made would be entirely altered. It is true the bulge was of small extent, but Mr. Watts was justified in assuming that in the separated after part of the hull, which was not found, it might have been of greater magnitude. Whether scantling in these special vessels should be made stout enough to allow of a considerable bulging in of the structure without endangering the strength of the hull to resist hogging and sagging strains under extreme conditions, is a matter to be determined by those who direct the amount of risk that should be run; that is, the naval officer. The naval architect can only give professional instruction and abide by the decision of the ultimate authority.

We must not forget, however, that torpedo craft have been built which have proved themselves able to stand the roughest usage. There is the well-known case of the Thornycroft torpedo boat *Hugin*, built for the Swedish Navy, which ran on to jagged rocks at a high speed, and remained with her after end from nearly amidships unsupported, without damage to her structural form. Our pages have contained from time to time particulars of many torpedo boats and torpedo-boat destroyers having made distant voyages to all parts of the world, meeting often with the extremes of bad weather without damage of any kind, notably twelve destroyers built for Japan, six by Messrs. Yarrow and six at the Chiswick yard, which made the voyage out without mishap.

A matter that may have affected the result of the *Cobra's* last voyage was the fact that certain weights, in shape of armament

and stores, were not on board. This was not considered of great importance by some of the professional witnesses at the court martial, but the fact is worth noticing. As the ship gave way owing to sagging strains, any weight left out of the end compartments would be liable to aggravate the evil effect by the ends being too floaty. Naturally a ship should not depend on movable weights for safety, but, as these weights might be usually on board in any given craft, it shows how a vessel may possibly often go through bad weather, and yet come to grief at last. The *Cobra* at full-load draught was 490 tons displacement; her total coal storage was 106½ tons, and when she left the Tyne her displacement was 468 tons. What coal was on board, and what was its position at the time she foundered, doubtless cannot be ascertained, but the fact would be useful to know. The absence of 22 tons weight would, Mr. Perrett stated, increase the buoyancy at the ends, but as the amount was equally distributed, he did not think it would materially increase the tendency to sagging. Again, it would be interesting to have definite figures in regard to this point. Another detail that can hardly escape notice is the fact that the girders under the boilers were buckled through heat, a fact noticed by Mr. Pine, who surveyed the vessel for the Admiralty. This witness, a first-class Admiralty constructor, was of opinion that the vessel was quite fit for any service because she had had at least half a dozen trials at sea in very bad weather, but had shown no signs of straining. He also bore witness to the very high-class nature of the riveting and workmanship. Mr. Deadman, a chief constructor, also considered the alterations to the vessel were satisfactorily made, and that the hull was well built, so as to be capable of meeting all contingencies of service as far as that class of vessel was concerned. He stated that the design rested with the contractors. It is not the practice of the Admiralty to tie down those who build destroyers to any special scantlings, although a minimum is specified. Under these circumstances it is evidently incumbent on the Admiralty to take care that contractors entrusted with the building of these vessels should be firms who have the necessary knowledge for the business, as well as a trained staff

of workmen skilled in the special work. The desire, doubtless laudable in itself, to "extend the area of competition" is, perhaps, accountable for a good deal of the trouble that has arisen in connection with these craft.

It is to be hoped that the large body of persons who take a laudable but often not very instructed interest in the Navy will not give way to excessive panic on account of what has occurred. As we have said on previous occasions, torpedo craft are a necessity to the complete efficiency of the fleet. They may or may not prove as efficient in actual war as their supporters and admirers maintain, but the torpedo is a weapon of such immense possibilities that no navy can afford to ignore it. Speed is the first essential to successful torpedo operations, and speed means lightness. There is no doubt in the minds of those who have most experience in the construction of these craft that, on scantlings now common, staunch and safe vessels can be built fit to make long ocean voyages and keep the sea boldly in all weathers. To do this, however, the design, materials and workmanship must be absolutely of the best, and to secure these ends the Admiralty must put a good deal of confidence in their contractors. That does not imply there should be any relaxation in inspection or tests, but rather that more flexibility should be shown in taking suggestions. The overseers sent down from Whitehall are all good men and trustworthy, but they have not had the same special training in this complex form of construction that has fallen to the lot of the firms who make the work their whole study, and who build so largely, not only for our own Government, but for the other naval powers.—"Engineering," October 18, 1901.

THE STEAMBOAT EQUIPMENT OF WARSHIPS.

[Paper read by E. C. CARNT, before the Glasgow International Engineering Congress, 1901. Section IV: Naval Architecture and Marine Engineering.]

To-day, when steamships are universal in the navies of the world, it is quite in the proper order of things that some of the small craft attached to and carried by the various classes of warships should be similarly propelled; but in order that the de-

velopment of the modern steamboat equipment of warships may be followed, it seems necessary to refer back to the time when steam was in its infancy for warship purposes.

When we consider that before the introduction of marine steam engines, generations of sailors in sailing ships, equipped with boats propelled by oars and sails, had made history, and were able to execute difficult maneuvers in war time, it is quite easy to understand that naval men were likely to be self-reliant, and in no need, so far as they could see, of the introduction of steam propulsion either into ships or boats. When we add to this spirit of self-reliance their innate dislike, due to the cleanliness to which they had been accustomed by years of routine, to soil the spotlessly clean decks of the ships and their no less clean boats by the coal, soot and ashes, which accompanies steam engines and boilers, it is not a matter of surprise that the application of steam as the means of propulsion to both ships and boats made slow progress in the early days, and that up to the year 1865–6, we find the steam launches in use in the British Navy were few, and those few slow and heavy. They were 42 feet long, about 11-foot beam, and had a speed of 7½ knots; the hulls were built in the Royal Dockyards, and the machinery was built by firms of the standing of John Penn, Maudslay and Field, J. G. Rennie, &c.

The arrangement of machinery was twin-screw, one engine being placed on each side of the boiler firebox. The boiler was generally of a modified locomotive type, although a return-tube boiler with flattened sides was sometimes used.

The weight of machinery with steam up was about 4 tons, the indicated horsepower 30 to 35.

These boats were attached to depots, and were carried at sea by the largest class of ships. They were principally used for communicating with the shore, from ships lying in the outer roadsteads of naval ports.

They were very useful, durable boats, and most of them ended their careers towing lighters of stores, and taking working parties to and from men-of-war fitting out and repairing.

The rowing and sailing boats which formed, in addition to these

steam launches, the equipment of the larger vessels, and in the smaller vessels the entire boat equipment, had in the meantime been brought to a high pitch of perfection, particularly as regards the small sailing lifeboats which were attached to nearly every ship in the Navy; and in this connection I trust it may not be considered out of place for me to mention the name of Mr. John White, of Cowes, Isle of Wight, who had, among other life-saving appliances for use at sea, made a special study of the manufacture of sailing lifeboats of such dimensions as to be easily carried at davits in all classes of ships.

These sailing lifeboats form the first step towards the evolution of the modern steamboat for warships. The next step, viz: applying steam machinery to these already satisfactory lifeboat hulls, was also taken at Cowes, by Mr. John Samuel White, who carried out in 1864 a series of experiments with one of the small lifeboats built under his father's patents. Others, no doubt, were fitting machinery to small lightly-built boats about the same time; but the experiments above referred to had a definite object, viz: the development of a steamboat for naval purposes, to meet as far as possible all conditions of service, whether in fine or stormy weather.

The engineers associated with Mr. White in carrying out his ideas were Messrs. Belliss and Co., of Birmingham, who, up to the year 1889, constructed the machinery for all the boats built by Mr. White (about 830 in number). The results of these experiments were embodied in a small steam life-cutter 24 feet in length, built for the yacht of the then Marquis of Hastings. This boat attracted the attention of the naval authorities, and an order was given to Mr. White to build a 27-foot life-cutter for service with H. M. S. *Sylvia*, for surveying work, a form of boat work which is of a very arduous nature for rowing boats. The boat was 27 feet long; the boiler pressure, 65 pounds; revolutions of engines, 278 per minute; and the indicated horsepower, 13½. The speed was about 7 knots. When this boat was delivered to Portsmouth dockyard, various experiments were carried out, as she was a new type, with a view to ascertaining her "lifeboat" qualities. She was allowed to fill from the sea,

and in this condition she still floated, with machinery, coal and crew in place. It was also found impossible to capsize her by ordinary means. The reliability of these harbor tests was confirmed on actual service soon afterwards. Whilst crossing a bar on the East Coast of Africa she was filled by a heavy sea, but did not sink or turn over. The boats of an American man-of-war, which were crossing the bar at the same time, were capsized, the crews being thrown out of their boats. The *Sylvia's* boat saved the crews.

The next step taken towards our modern naval steamboat was the building by Mr. White of a 36-foot single-screw life-pinnace, with a total weight of machinery not exceeding 40 cwt.; this boat was completed and tried in 1867. She was called *Steam Pinnace No. 2.*

The results were briefly as follows:

Boiler pressure, pounds	70
Revolutions	289
Indicated horsepower	31.29
Speed	8.322

The engines were vertical, non-condensing, with two 6-inch cylinders by 6-inch stroke, exhausting through a silencing tank into the funnel. The boiler was of circular launch type, with wet-bottom furnace. She was equal in towing power to the 42-foot service launches of the old type; and with all weights on board, and filled with sea water, she sustained afloat thirty men, whose united efforts, rushing from side to side on the thwarts, failed to capsize her, there being still a considerable surplus of buoyancy, even when in this condition. These trials had, no doubt, a great influence in the selection by the Admiralty (of that date) of this type of boat for all future steam cutters and pinnaces for the Navy; and until 1878 these boats remained the standard for warships' steam boats, slight modifications in over-all dimensions being made from time to time, to suit the requirements of the service. I believe there were some 300 of them built, and many are still running.

In 1878 a desire for increased speed led to two boats, each 48 feet long, being built, one twin-screw and one single-screw.

The engines were compound; forced draft on the close stokehold principle was applied to the boiler, a surface condenser of the inside type was fitted, the circulating pump being worked off the engine shaft in conjunction with an air pump. A considerable increase of power for the same weight of machinery was obtained by these means, and the speed of the boats increased. The two boats referred to were officially tried and accepted, with results as follows:

In February, 1880, the twin-screw boat obtained a speed of 13.39 knots, with a collective indicated horsepower of 121.22.

In August, 1880, the single-screw boat obtained a speed of 12.148 knots, with an indicated horsepower of 86.9.

The speed of the "service steamboat" being now (1880) brought up to 13 knots, it was next considered, in view of the development of the Whitehead torpedo at this date, and the advantage which rapid power of maneuvering would give a vessel armed with this weapon, how to improve these qualities in these fast little pinnaces, with a view to utilizing them in connection with torpedo work.

The "double-rudder turnabout boat" was evolved and patented by Mr. White, and in 1881–2 a single-screw 48-foot boat, fitted with this system, was purchased by the Government, and formed part of the boat equipment of H. M. S. *Inflexible* in her first commission.

The effect of the turnabout principle is remarkable, and is readily appreciated by those who witness the handiness of a boat so fitted at all rates of speed, either ahead or astern.

To reduce the comparison of boats fitted with ordinary rudders and those fitted with double-balanced rudders, which form the turnabout principle, to figures, we will take the following records:

Type of boat	Ordinary.		Turnabout
Length of boat	48 feet.		56 feet.
Engines	Single screw, full power.		Single screw.
	To starboard.	Port.	
Angle of rudder	40 degrees.	40 degrees.	45 degrees.
Full circle time	1 m. 21 s.	1 m. 19 s.	28 s. 37 s.
Number of revolutions per circle	508	456	182 177
Diameter of circle	170 yards.	153 yards.	126 feet.

Thus, the shorter ordinary boat wishing to turn a circle at full power, requires four times the room to turn in, and occupies more than twice as long a time in turning than the turnabout boat.

The next departure (in 1883) was to increase the length of the 48-foot boats to 56 feet, and the beam to 9 feet 6 inches (these dimensions bring us to the present day, as the 56-foot vedette boats is the largest boat carried by first-class ships now), the double-rudder system was retained; a single screw was fitted.

In December, 1883, one of these 56-foot boats was officially tried on the measured mile in Stokes Bay; the indicated horse-power developed was 142, and the speed 15.562 knots, with 385 revolutions per minute. The boiler pressure was 125 pounds per square inch, and the air pressure in stokehold 2.75 inches of water. The coal carried was 6 cwt.

This class of boat was known in 1883 as "Torpedo-boats wood." They were fitted with side-dropping gear for Whitehead torpedoes, and with their relatively high speed and extreme handiness were not to be despised when taking part in a night attack.

Torpedo warfare was now attracting great interest, and the steel second-class torpedo boats built by Messrs. Yarrow and Thornycroft were designed to form part of the steamboat equipment of the first-class ironclads, of special torpedo dépôt ships and cruisers of the *Leander* type. These little craft, weighing about 12 to 14 tons, were hoisted into the ships, to which they were attached by means of specially-arranged derricks and boat-hoisting engines, and were stowed in crutches on each side of the funnel casing.

Steel torpedo boats, however, rapidly increased in size and speed, and were deemed capable of accompanying a fleet at sea; and as the second-class boats were not suitable for the general work of the ships to which they were attached, they were gradually discarded as part of the boat equipment, and wooden boats are carried instead. These are better sea boats, are all-round working boats, and can do the special service for which the second-class boats were intended.

The derricks and boat-hoisting engines originally provided for

the steel second-class torpedo boats have been retained and developed, and are now fitted to all classes of ships carrying heavy boats.

The experimental "torpedo-boat wood" having justified her construction, the title was allowed to drop out as regards boats carried by ships; and as ships increased in size the 56-foot dimension was retained, and the boats included under the head of "Vedette Boats."

From 1883 onward the progress made in marine engineering and shipbuilding has been reflected on the designs of the small craft under review. Changes have gradually been made in the 56-foot boat design, the hulls have been modified, a rifle-proof conning tower has been fitted forward, the side air-casings or lifeboat principle has been abolished, and the boats divided up into water-tight compartments by bulkheads. The engines and boilers are cased over, and the boat decked in right aft to the cockpit. The indicated horsepower has been increased, water-tube boilers substituted for the locomotive type, and as a result the 56-foot service vedette boat of to-day will travel at 16 knots, while developing 250 indicated horsepower, carrying a load of twelve persons, and with 25 cwt. of coal in the bunkers. The weight of machinery with steam up being 7 tons 15 cwt. The turnabout principle has been retained, and this very fast, handy type of boat might easily be called the "hansom cab" of the fleet, as compared with the next size, the useful, hardworking "four-wheeler" 40-foot pinnace. This boat is a deadwood boat as distinct from a "turnabout," has a specified indicated horsepower of 75, and obtains a speed of about 9¼ knots.

It is decked in and machinery cased over as far aft as the cockpit; the lifeboat principle of air casings is discarded except in the forepart, abaft the collision bulkhead; the boat is, however, divided into water-tight compartments by bulkheads carried right up to the deck. The engines run at 500 revolutions, the boiler is of water-tube type, and is worked under forced draft on the closed-stokehold system, a separate fan engine being fitted. The engines are surface condensing, a pipe condenser being placed outside the boat close to the keel. These boats are

fitted with offensive weapons, torpedo-dropping gear, and a small gun.

In flagships, a modified 40-foot pinnace is carried as a barge for the Admiral Commander-in-Chief, unless the flagship has no boat-hoisting derrick, as in second-class cruisers, when a 32-foot barge only is carried.

The barges are more ornamental than the pinnaces, and have no armament fittings. The other standard steamboats are the 32-foot cutters and 32-foot barges; 27-foot cutters and 23-foot cutters. These, from the 32-foot boats downwards, greatly resemble the 32-foot lifeboat pinnace built in 1867; except that the lifeboat principle is not always followed, although the steamboats of the new *Victoria and Albert* are on the old lines, and lifeboats thoughout.

The surveying boats are also lifeboats.

The machinery of the various sizes of boats has been brought up to date, the engines compounded, a pipe surface condenser fitted outside the boats, and a fan worked by a steel-spring belt from the main engines discharges air into the ashpits. The boilers are of much the same type as the 1867 boats, but, working in conjunction with condensed water, are more efficient and last longer than in the old high-pressure days.

The noise of the funnel exhaust, together with its occasional shower of sooty water from the top of the funnel, are things of the past.

The establishment of boats of the various classes of ships in the British Navy is as follows:

	Pinnaces.		Barges.		Cutters.		
	56 ft.	40 ft.	40 ft.	32 ft.	32 ft.	27 ft.	23 ft.
First-class battleships	2	1	...	...	...	...	...
First-class battleship, if flagship	2	1	1	...	...	...	...
First-class cruisers	1	1	...	...	...	...	...
First-class cruisers, if flagship	1	1	1	...	...	...	...
Second-class cruisers	...	...	...	...	1	...	...
Second-class cruisers, if flagship	...	...	...	1	1	...	...
Third-class cruiser	...	...	...	...	...	1	...
Torpedo-gunboat Sloops	...	...	...	...	...	...	1
Surveying ships	...	...	...	...	...	1	...

With the construction in this country of warships for foreign navies, the question of equipment of steamboats is brought forward, and we find the Japanese Navy adopting two 16-knot 56-foot vedette boats and an open boat as the steamboat equipment for the battleship *Mikasa*, building at Barrow.

The Russian Government require two 56-foot vedette boats and two 40-foot pinnaces for a vessel building for them in France. These four boats are of steel, and very fully equipped.

The Austrian Government use a 47-foot wooden turnabout boat with a speed of 11 knots, and are now adopting a specially fast wooden vedette boat 56 feet in length.

In connection with the vessels recently built by Messrs. Armstrong, Mitchell and Co. for the Japanese Navy, four 56-foot vedette boats were required.

The possibility of giving these four boats a speed of $17\frac{1}{2}$ knots under certain specified conditions was considered.

This required careful looking into, and the final design became a 56-foot boat, with a ram bow which increased the water-line length about 9 inches.

The hull was very carefully lightened consistent with durability where possible, and the total weight of machinery kept down to 8 tons. The engine was compound, with $\frac{8\frac{1}{2} \times 18}{9}$ cylinders; a water-tube boiler, with a working pressure of 190 pounds, was fitted.

On the private trial the boat gave an exhibition of speed that was scarcely hoped for, viz: $19\frac{1}{2}$ knots. The engines developed 320 indicated horsepower at 565 revolutions without vibration.

A series of progressive trials were carried out with this first boat. On the official trials of the four boats, with the load conditions as specified, the mean results were as follows:

——	Revolutions.	Indicated horsepower.	Speed.	Date.
Nos. 1.....	548	297	18.322	May 2, 1900.
2.....	540	297	18.1	May 2, 1900.
3.....	538	302	18.25	June 6, 1900.
4.....	543	292	18.32	June 6, 1900.

These four boats are, it is believed, the fastest vedette boats in the world.

A similar boat is being built for the Austrian Government; this will shortly be completed, and equally satisfactory results are anticipated.

It will be noticed that even so far back as 1864 the revolutions of the engines were high (278 per minute), and that they have still increased until, at the maximum speed of the four boats for the Japanese Navy, we are running at 565 revolutions per minute, with an open two-cylinder compound engine, with carefully arranged balance weights on two cranks at right angles to each other.

Familiarity and experience with such fast-running engines undoubtedly led Messrs. Belliss and Co. in the direction of their "quick-revolution electric-light machinery;" a later development of which is closing in the engine and applying forced lubrication to the bearings, with a view to running for long periods at a high number of revolutions without excessive wear and tear. This class of machinery is doing its work satisfactorily for electric-light stations and on shipboard; and now a 30-knot torpedo-boat destroyer, built by the Palmer Shipbuilding Company, of Jarrow-on-Tyne, fitted with a forced-lubrication system, and with engines closed in, is about to be officially tried in the Solent.

This class of machinery for the fast vedette boats has been looked into, and a design prepared ready for use; but as we are already running up to 560 revolutions with an open engine, it will probably be some time before this number will need to be increased; and as the matter of wear and tear is hardly one which seriously affects boats with small coal supply and running short trips, it becomes a question whether it is necessary to close in a small engine and make it less accessible for examination.

The Admiralty boats are all built of teak, and undoubtedly this is a most serviceable wood for all conditions of service and exposure to tropical weather; but in all the early boats mahogany was invariably used, and we now prefer it for high-speed

boats, as it makes, size for size, a lighter hull, and may be considered, for all practical purposes, equally durable.

THE RUSSIAN 25-KNOT CRUISER *NOVIK*.

In past issues of the "Engineer" we have already given a plan of the *Novik* and a full description of her armament, &c., in comparison with the British *Pelorus* class and the German *Gazelle* type. It will be necessary here, therefore, merely briefly to recapitulate these details.

The particulars of the *Novik* are: Displacement, 3,000 tons; length, 361 feet; beam, 39½ feet; draught, 19 feet; armament, six 4.7 inch-45 caliber, eight 3-pounders; torpedo tubes, five above water;* armor deck, 2 inches; indicated horsepower, 17,000; speed, 25 knots; boilers, Thornycroft; screws, three.

It may be mentioned that all cruisers of this sort have, as it were, two existences,—a "paper" one and a real one. The "paper" *Novik* is a ship of a type apart, a "destroyer of destroyers," and what not. That is her theoretical *métier*, and the one with which our previous article dealt. We will now consider the real *Novik* and her limitations.

In the matter of armament she is practically identical with the German *Gazelle* type, only instead of the ten 3.9-inch of this type—five guns to the broadside—the *Novik* has six 4.7-inch—four guns to the broadside. Presumably a lightly armed ship, she is actually, when the relative values of the different calibers are taken into account, better and rather more heavily armed than the *Gazelle*, and a good deal better armed than our *Pelorus*, which has but four 4-inch to the broadside. If we reduce the guns to a common denomination, on the understanding that while two 4.7's are about equal to one 6-inch, it takes three 4-inch to attain the same shell fire value, we get—taking only one broadside fire:

Novik's broadside is equivalent to 2 6-inch.
Gazelle's broadside is equivalent to 1⅔ 6-inch.
Pelorus' broadside is equivalent to 1⅓ 6 inch.

* A bow tube in the original design has been suppressed.

As, however, the relative displacements are: *Novik*, 3.000 tons; *Gazelle*, 2,600 tons; *Pelorus*, 2,200 tons; we find that, by dividing the gun-fire units into displacement, then the relative ratios of merit in this respect are:

Pelorus has the equivalent of a 6-inch for every 1,650 tons.

Gazelle has the equivalent of a 6-inch for every 1,560 tons.

Novik has the equivalent of a 6-inch for every 1,500 tons.

That is counting guns that bear on one broadside. The duplication of bow and stern guns in the *Pelorus* and *Gazelle* is of little practical value, save for immediately end-on fire; and since to use this the vessels will have to take the suicidal risk of being raked, it may be entirely disregarded as a practical asset. We find, therefore, that the *Novik*, both relatively and actually, is the best armed ship of the three. Curiously enough, however, she is the only one that has been characterized as "too lightly armed."

This is due presumably to the relatively small total, and the giving of a value to the other broadside. In stern fact, the other broadside will be valueless. What destroys a gun one side is sure to destroy on the other side at the same time if the ships are fighting broadside on. In this respect the *Gazelle* is worst off, her guns being in but three groups, while the *Pelorus* has four. The *Novik*, perhaps, is little better off than the *Gazelle*, her three after guns being bunched, so that in a practical asset of this sort most intelligence would seem to have been exhibited in the British ship, which has most distribution. All in all, however, the *Novik* must take the palm as the best armed ship of the trio.

We have shown above the gun-fire values per ton of displacement. It may be mentioned that a ship like the *Majestic* works out a 6-inch gun, or equivalents, per 900 tons, if only one broadside is reckoned. As in such a vessel an off-side armor-protected broadside may well be to a certain extent "saved up," the proper comparative proportion is even less, being about one per 650 tons. In fast cruisers like the *Cressy* it is one per 800 tons odd. Incidentally, this might well be used as an argument against small ships; the *Cressy*, despite all the armor she carries, having

as good speed as the *Pelorus*, and twice as much gun power per ton of displacement. However, our present purpose is the discussion of a narrower question than the fascinating and highly-complicated problem as to which is the most economical displacement for a warship. It suffices here merely to point out that—despite popular belief—small ships are, in displacement to guns, obviously not good value for the money, and that they have nothing to show by way of compensation for the loss of armor, save, in the case of the *Novik*, a 4-knot gain in speed. Even so a 25-knot *Cressy* would probably be cheaper.

Still other questions enter, and, by reason of these small ships, will probably always exist. They have the power of numbers, and numbers are essential for scouting and kindred uses. They represent, therefore, "the price of Admiralty" in its least economical form as regards displacement. This once realized, the question swiftly whittles down to whether it is better to build 3,000-ton 25-knot ships like the *Novik*, or smaller vessels like the *Gazelle* and *Pelorus*, that have no runaway speeds, but which individually represent a good deal less expenditure in pounds, shillings and pence, either as ships or per ton. The extra cost of the *Novik* has not been stated, but it is known to be very high—probably over £250,000. The *Pelorus* class costs approximately £140,000—some are more, some less—the *Gazelle* class £165,000, or thereabouts. A *Cressy*, which is about five and a half times as big as the *Pelorus*, costs about £750,000, say, from five to five and a half times as much, but would, in a battle, sink five or six *Pelorus* class ships without being much, if at all, hurt in return. It is strategically, therefore, that we must consider the problem. Tactically, the small ships are waste of money.

Here it is necessary to remember that full speed is a relative term. The full speed of a man may be well over twenty miles an hour if he sprints for a short while, but when he is used for war his progress rarely exceeds three miles per hour, or thereabouts. Ships are much the same, though not to the same degree, especially small ships. Coal supply will not allow long races at high speed, neither will human endurance below. The smaller the ship the more difficult it is to maintain high speed. Thus, a

21-knot *Cressy* would, given sea room, be almost absolutely certain to overhaul a 21-knot, or for that matter may be a 22-knot *Gazelle*, just as this last would overhaul many nominally fast destroyers. *Gazelles* and *Peloruses*, in fine, are built on a frank, if unexpressed, assumption that the loss of one or two will not matter. They are built to do a certain amount of work and then go to the bottom—a theory that may work well enough, given an unlimited number of such ships and unlimited men for them. Failing these requisites, only time is required to exterminate such vessels. One *Novik* that can hardly be caught is, from this point of view, worth two *Peloruses* that can be, for the wastage of men is less, and a less number will go further and last longer.

So far, so good. But there are other issues. When an enemy is to be found or his trade attacked, six *Peloruses* seem more able to find and destroy them than three *Noviks*, so that the only advantage left to the *Noviks* is speed. Now is 25 knots enough to insure showing heels to 21-knot *Cressys?* We are by no means certain that it is. The strain of keeping up that speed, or anything like it, in a small ship will be tremendous. Again, too, there are 23-knot ships, like the *Essex*, *Drake* and *Bayan* classes. Can such be evaded? We very much doubt it. Even in an ordinary sea-way the weight of the slower ship will tell—the smaller the vessel the more difficult must it be for her to attain her speed in anything save ideally smooth water. And ideally smooth water rarely exists outside paper calculations.

On paper, of course, it runs thus: The 25-knot ship is five miles ahead, say, when chased by the 23-knot ships. She gains two knots every hour. Therefore, in ten hours she is twenty-five miles away.

It is beautifully pretty and simple, and it is argued most days of the week. But is it really likely to happen? Let us glance a moment at probable facts.

The 25-knot ship we will call *A*, the 23-knot ship *B*. *A* is presumably cruising, and perhaps has steam for full speed—though this is taking an assumption. She is, perhaps, making 18 knots, and seeing *B* "cracks on," and does a 21 or so, which gradually drops to 17. *B* also "cracks on," and, being less in-

commoded by the sea, may manage a fairly steady 21, dropping slowly to 20 or 19. In ten hours *A*, if "twenty-five miles away," will probably be so as a doubled-up wreck, 2,000 fathoms down, and *B* proceeding elsewhere at 17 knots. Such, at least, is the lesson of chases in naval maneuvers.

Thus is the problem twisted and complicated. Numbers must exist to scout, but the smaller the units the less likely are they to survive. Hence it comes about that it is hard to find a justification for any mean between the big cruiser of 10,000 tons or so and the destroyer, save for certain fixed uses, such as commerce destruction, a thing that our Navy will not be called upon to exercise much. Hence we seem to have small need for *Noviks*. Even in the rôle of destroyers we are somewhat sceptical of the value of the 25-knot ship. They will overhaul destroyers, no doubt, but so, somehow or other in practice, do 19-knot cruisers. A couple of destroyers chased by a *Novik* are more likely to be able to torpedo her than a *Cressy* with ten times the gun fire.

Some such line of thought seems to be in process of being acted on by the British Admiralty, the ten new destroyers being evidently designed to act as scouts, if need be. No more third-class cruisers are being perpetrated, and a suspicion exists that the *Encounter* and *Challenger* are building as much to swell the total of "cruisers" as for any particular faith that is held in them. Between the *County* class and the new destroyers an enormous gulf exists, and that gulf is likely to be allowed to remain, unless popular agitation calls for *Noviks*. And, as we have indicated, the practical value of *Noviks* yet remains to be proved. Like several types of warships, their finest qualities work out in theory only. With destroyers, on the other hand, we know where we are. The mere sight of them upsets an enemy's *morale*, they have shown in maneuvers that they can scout well, and when scouting is done and the battle joined, other uses for them at once begin.—"Engineer."

THE SUBMARINE BOAT.

At the present time the French have thirty-four boats in various states of manufacture, twenty-nine of which are electric sub-

marine and five submersibles, and they are now carrying out important trials and spending large sums of money in their development. Before many years have passed France will have not thirty-four but hundreds, with which she would be able not only to protect her ports, but to make attacks on our fleet in much the same way as the bands of Boers are making guerilla attacks on our regular army in the Transvaal. Of the continuous stream of ships passing up and down the English Channel—the busiest steamship track on the globe—quite 90 per cent. are British vessels, and upon them our mercantile greatness depends. Let us suppose that in time of war 100 French submarines were let loose in the channel at night. These boats have sufficient speed and radius of action to place themselves in the trade routes before the darkness gives place to day, and they would be capable of doing almost incalculable destruction against unsuspecting and defenseless victims. The same applies to the Mediterranean and other of our ocean highways within the danger zone of the submarine. The submarine boat has thus increased the value of the mechanical torpedo ten fold.

To the United States of America the submarine will be of inestimable benefit, as it will render the coast practically secure against attack from any country, excepting those having naval bases within easy striking distance of their littoral. The boat now universally adopted by the United States is built on the Holland system, and the new British boats building by Messrs. Vickers, Sons & Mamim, Limited, at Barrow-in-Furness, are of similar design. They are to be equal in speed to the French boats, and have other qualities not attained by these boats, the principal of which is that they will be capable of behaving much in the same way as a porpoise. They are capable of coming up and disappearing instantly, so that they can thus determine exactly the mark to be aimed at before discharging the torpedo. The quality of being able to dive in a few seconds renders them much less vulnerable to attack by artillery.

As to the periscope, of which the French speak so much, there is no doubt that when cruising submerged in the proximity of the enemy it will be very useful. It is an arrangement whereby

a view of the surface from 30 to 50 degrees can be obtained, and enables the boat when submerged to be steered directly for a visible point. The Holland boat has a special arrangement for effecting this purpose, while enabling her to run at a distance below the surface, so that no visible trace of her can be seen. Such an arrangement places this country quite on a level with the French nation, notwithstanding the fact that we may not have given the same amount of attention to submarine warfare. It is true the speed of the submarine boat is not great, but progress is certain. When the Whitehead torpedo was first introduced it had a low speed, and, generally speaking, was very uncertain as to its direction, depth and applied utility. Now, however, it is capable of running within a few inches of the required depth, at a speed of over 27 miles an hour for a range up to 2,000 yards, and hitting the point aimed at with almost the same precision as a gun. In the same manner there is no doubt the submarine boat will be improved, while there is a great field for development in connection with the electric battery.—"Engineering."

POWER REQUIRED TO DRIVE A MARINE ENGINE WORKS.*

By Messrs. James Crighton and W. G. Riddell, of Glasgow.

It is not the intention of the authors to attempt to describe a model engine works or driving plant, but rather to enumerate and show the result of a few improvements which have been adopted by the firm with which they are connected.

About three years ago it was decided to rearrange the works in a thorough manner, and to fit up a new power installation. The works had gradually grown during upwards of thirty years, and most of the buildings were in excellent condition and in no need of reconstruction. The problem to be solved, then, was how to lay down an economical driving plant which would conform to the existing conditions, and which would not lead to an unnecessary sacrifice. At that time the motive power of the

* Paper read at the International Engineering Congress, Glasgow, 1901. Section III; Mechanical.

works consisted of one marine-type boiler working at 80 pounds pressure, and supplying steam to three vertical, compound engines for driving the machinery, and one vertical, compound engine for lighting purposes. The points in favor of so many units were the saving in steam when running one or two machines at night, which might be driven by one of the small engines; and also the fact that in the event of a breakdown of one engine, the other parts of the works were not affected.

It was, however, decided to put in one engine capable of driving and lighting the entire works, and to meet the difficulty of late work, by driving those machines which experience showed were the most likely to be needed at night by motors which could be connected with current from the Glasgow Corporation. The engine was made to a simple design, in order to make the fear of a breakdown very remote. A cylindrical marine boiler, designed to work under either forced or natural draft, was selected as the most suitable type, and has proved itself both economical and reliable. The position of the power station was fixed to a certain extent by circumstances.

The works are situated in a busy part of the City of Glasgow, where ground is costly and economy of floor space essential. There is no direct communication with any railway, so that all material has to be carted to and from the works. Close proximity to the street was therefore an important factor in settling the position of the boiler. The position chosen was between the engine and boiler departments, and as the difference in the floor level of these departments is about six feet, the boiler was placed on the lower level, and the coal tipped over into a bunker in front of it. The ashes were returned by an hydraulic hoist to a receiver raised above on the higher level, under which a cart might be filled automatically. The engine was placed as near the boiler as possible, with the crankshaft parallel to two of the main lines of shop shafting. Two dynamos were laid down for lighting and driving purposes, and these and the lines of shafting were connected to the main-engine shaft with belts, and all so arranged as to be easily disconnected. Motors were laid down to drive all outlying shafting.

The existing conditions having been treated in a general way, the driving plant will now be described in detail. The boiler is of the cylindrical marine type, 13 feet 6 inches mean diameter by 12 feet 6 inches long, and is fitted with three Morison suspension furnaces, 3 feet 1 inch inside diameter by 8 feet long. The working pressure is 200 pounds per square inch. The firebars are 5 feet long, and the grate area is 46.2 square feet. There are three separate combustion chambers and 316 tubes, 2½ inches external diameter by 8 feet long, the total heating surface is 2,040 square feet, being 44.2 times the grate area. The length of the chimney above the firebars is 65 feet. A 60-inch fan is provided to blow air into the furnaces through fronts of the Howden type, and the boiler tubes are fitted with retarders. The boiler is covered all over with non-conducting material, and the loss from radiation is so small that 3 cwt. to 5 cwt. of coal is sufficient to keep up the steam pressure during the night when the engine is not working. A Craig's combustion tester is kept in the boiler room, by means of which the percentage of carbonic acid gas in the uptake may be read at sight, and the air supply reduced to the point where efficiency begins to decrease. The feed water is heated by exhaust steam, and enters the boiler through a Kennedy water meter at a temperature of 205 degrees Fahrenheit.

Numerous evaporative tests were carried out with different kinds of coal. The coal and ashes were measured, and the capacity of the measure was frequently tested, and the water meter was read at regular intervals. It was, however, found that even the absence of a desire for phenomenal results did not prevent the weight of the coal burned at the tests from being apparently less than the weight passed over the weighbridge. The difference was sometimes as great as 5 per cent., after deducting coal used for keeping up fires at night and for lighting fires at the beginning of the week. Measuring was, therefore, discontinued, and the weight of coal passed over the weighbridge taken as the amount burned. The water meter was read at stopping time each Saturday, and continuous weekly returns

showing the cost per 100 gallons of water evaporated were made up from the figures thus obtained.

The tabulated tests of the boiler were made when the alterations to the driving plant were incomplete, and the amount of steam required was greater than is used in ordinary circumstances. It is probable, however, that, owing to additions to the works and new machine tools, the quantity of water evaporated at these tests will ultimately be required. Now that all the power in the works is derived from one engine, less steam is being used, and the rate of combustion per square foot is less and the efficiency slightly greater. Notwithstanding this, the tests taken at the higher rate of combustion have been used in this paper as the basis for calculating the cost of power as, in course of time, the conditions prevailing at these tests will be the normal working conditions of the boiler.

Trials of the boiler were carried out for four consecutive weeks, with a different kind of coal each week. The coal was tested daily during the four weeks with a Thomson's oxygen calorimeter. During the first week the cheapest quality of coal which would give the required amount of steam was used. This cost 8s. 10d. per ton, and goes by the local name of "washed singles." It had a low calorific value of about 10,000 British thermal units per pound. The rate of combustion was fully 40 pounds per square foot of grate per hour, and when burning this quantity great volumes of black smoke were given off.

"Washed doubles" or "nuts" was the next quality tried. It costs 1s. per ton more than "singles," and had a slightly higher calorific value; but its evaporative power was not worth the extra 1s.

The third test was made with "steam coal triping" at 10s. 6d. per ton. The great defect of this coal was the large proportion of fine dust contained in it. An air pressure of $\frac{5}{8}$ inch had to be maintained in the ashpits in order to burn it quickly enough, and this carried the dust away before it was burned. It lodged in crevices of the smokebox, where it took fire and did damage.

The fourth and last coal tried was steam coal at 11s. 6d. This coal had a calorific value of 14,320 British thermal units, and

gave all-round satisfactory results. The cost of evaporation was slightly higher with this coal than with "washed singles" —7.49d. per 100 gallons against 7.36d. per 100 gallons—but this was more than saved in wages. One fireman was able to attend to the boiler all day when firing steam coal, but had to be relieved when firing singles, the rate of combustion being so much higher with the latter.

In Table I a deduction of two tons was made in each case from the weekly coal consumption when finding the rate of consumption per square foot of grate. This is the amount used for keeping up steam at night and lighting the fires at the beginning of the week. The total weekly consumption was the weight taken in finding the other figures. It may be added that, after allowing for the error in measuring the coal, an equivalent evaporation of 11.5 pounds from and at 212 degrees Fahrenheit was frequently maintained for several hours at a time, but the losses due to stoppages for meal hours and cleaning fires reduced this to the figures given in the table. The grate area of the boiler is 46.2 square feet, and the heating surface 2,040 square feet. The feed temperature was 205 degrees Fahrenheit, and the steam pressure 200 pounds during all trials.

The engine is of the vertical, double-acting compound type, and is at present non-condensing. A cooling tower is being erected, but, owing to its position in the center of the works, it could not be completed sooner without disorganizing the establishment. The engine has cylinders 12½ inches and 23 inches in diameter by 21 inches stroke, and working at 200 pounds pressure per square inch. The cranks are placed directly opposite each other, and the slide valves of both engines are actuated by one eccentric and one valve spindle. At present the exhaust steam passes through a receiver to the atmosphere, the receiver being so constructed that it could be easily converted into a surface condenser when the cooling tower is ready, and this is now being done. The feed water meets the exhaust steam in the form of a spray, and is heated to 205 degrees Fahrenheit. It then falls by gravity to the float tank of a Weir's feed pump, and is pumped through a Kennedy water meter direct into the boiler.

In the design of the engine simplicity of parts and ample bearing surface were aimed at in order to minimize, as far as possible, any risk of breakdown.

The two main lines of shafting are driven direct by means of belts from pulleys on the main-engine shaft. Another belt is taken from the flywheel on the engine crankshaft to a countershaft, which countershaft in turn drives the electric generators. The generators are two in number, of the Schuckert type, designed for 110 volts and an output of 70 kilos each, which may be used alternatively for lighting and power. From a series of trials it was found that the engine was developing 147.27 indicated horsepower when driving the electric lights alone. This represented a mechanical efficiency at the generator terminals of 0.68, which may be considered fairly good, seeing that the engine was only working at slightly more than half load, and including, as it does, the losses in friction of the engine itself, dynamo countershaft and dynamo.

TABLE I.

Kind of coal.	Washed singles at 8s. 10d.	Doubles at 9s. 10d.	Steam coal triping at 10s. 6d.	Steam coal at 11s. 6d.
Coal burned per week, tons	47.15	46.25	40.4	37.3
Coal burned per square foot of grate per hour, pounds	40.5	39.7	34.5	31.4
Percentage of ash in coal	15	12	16	8
Total water evaported per week, pounds	715,000	713,300	715,400	715,000
Water evaporated per pound of coal actual, pounds	6.76	6.88	7.9	8.62
Water evaporated per pound of coal from and at 212 degrees Fahrenheit, pounds	7.16	7.29	8.36	9.13
Water evaporated per square foot heating surface, pounds	6.55	6.47	6.58	6.55
Temperature of uptake, degrees Fahrenheit	630	635	650	617
Air pressure in ashpits, inch	½	½	⅝	½
Cost of carting away ashes, shillings	10.6	8.3	9.7	4.4
Cost of fuel for evaporating 1,000 pounds water, pence	6.99	7.65	7.1	7.14
Total cost of 1,000 pounds of steam, including cost of water, coal, and cartage of ashes, pence	7.36	8.02	7.46	7.49

In order to find the power absorbed by the line shafting in the works a series of trials was carried out. At the first trial only the line shafting and loose pulleys were run. The machines and countershafts were run along with the shafting at the second trial, and the final trial was made with the machines cutting at their normal rate. The average diameter of the line shafting in the works is 3¼ inches, and its speed is from 140 to 150 revolutions per minute. It runs in white metal self-oiling pedestal bearings, spaced about 12 feet apart. The total length of line shafting in the works is 2,300 feet, and the weight is 37 tons 8 cwt. 2 qr. The engine indicated 61.75 indicated horsepower at the first trial, 141 indicated horsepower at the second, and 310 indicated horsepower at the third. From these powers it will be seen that the line shafting absorbs 29.3 per cent. of the total power, the countershafts and machines 67 per cent., and that only 33 per cent. is actually applied to the cuttingtools.

Before instituting a comparison between the old and new systems of driving the works, it may be well to enumerate briefly the various units which made up the old installation. These were:

1. A marine-type boiler, working at a pressure of 80 pounds per square inch. The feed water for the boiler was heated to 205 degrees Fahrenheit, as in the new boiler.

2. Three compound non-condensing engines, indicating collectively 151.2 indicated horsepower for driving purposes.

3. One compound non-condensing engine, for lighting purposes, of 64.66 indicated horsepower. The boiler evaporated about 6.75 pounds of water per pound of coal, and the engines used 43.8 pounds of water per indicated horsepower per hour. This gave an average coal consumption of 6.4 pounds of coal per indicated horsepower. In calculating the cost of a horsepower for a year, the coal used for raising steam for smithy hammers and blowing engines has not been taken into account, but the steam for electric lighting has been charged in each case, as it was almost impossible to obtain accurate figures without doing so. The proportion of steam used for smithy hammers was found by working the smithy under normal conditions for three nights of twelve hours each. The blower engines were also run at their

normal speed during this test. It will be seen that the power for electric lighting is much greater in the new than in the old system, and it may be contended that the greater efficiency of one horsepower in the new system of driving is partly due to the better-lighted workshops; but this is a refinement into which the scope of this paper does not permit of investigation.

It now remains to be shown by how much the new system is better than the old; in other words, at how much smaller cost it produces work. Since the power in an engine works is expended in removing material from rough castings and forgings, a figure may be found by which different systems may be compared; the system by which a given weight of material is removed at the smallest cost being the most efficient. In order to make the grounds of comparison similar, the cuttings produced by machines whose scrap is not in proportion to the power expended—such as shearing machines and band saws—are not taken into account, but the weight of all turnings, &c., for a fixed period is divided by the cost of one horsepower for the same period, and a money value for the power per ton removed can thus be obtained. From the following Tables, III to V, it will be seen that the cost of removing one ton under the old system of driving was £5.21 and under the new system £2.48, showing a saving by the new system of 52 per cent. Notwithstanding the saving, it is clear that when the surface condenser is fitted the cost of one indicated horsepower will be much further reduced.

It is hoped that the figures given may help to provide a basis on which to calculate the relative efficiency of the driving plant in similar works.

TABLE II.—COST OF ONE INDICATED HORSEPOWER PER YEAR OF 3,000 HOURS UNDER THE OLD SYSTEM.

	£	s.	d.
Coal—1,545 tons at 11s. 6d. per ton	888	7	6
Wages for steam raising	176	2	0
engine tending	194	1	0
Maintenance of engines and boilers	80	10	0
Oil, waste and sundry stores	23	16	0
Water—2,172,133 gallons at 30s. per 100,000 gallons	32	8	0
Cartage of ashes	11	11	0
Total	1,406	15	6

$$\frac{1{,}406l.\ 15s.\ 6d.}{\text{Mean I.H.P., } 165.2} = 8.5l. \text{ per I.H.P. per year.}$$

TABLE III.—COST OF ONE INDICATED HORSEPOWER PER YEAR OF 3,000 HOURS UNDER NEW SYSTEM.

	£	s.	d.
Coal—1,360 tons at 11s. 6d. per ton	782	0	0
Wages for steam raising	92	0	0
engine tending	200	0	0
Maintenance of engine and boiler	25	0	0
Oil, waste and sundries	28	10	0
Water—2,750,000 gallons at 30s. per 100,000 gallons	41	5	0
Cartage of ashes	10	4	0
	1,178	19	0

$\frac{1{,}178l.\ 19s.\ 0d.}{\text{Mean I.H.P. } 271.3} = 4.34l.$ per I.H.P. per annum.

TABLE IV.—OLD SYSTEM.

Material removed per annum, tons	245
per indicated horsepower per annum, tons	1.61
Cost of removing 1 ton of material, pounds	5.21

TABLE V.—NEW SYSTEM.

Material removed per annum, tons	367
per indicated horsepower per annum, tons	1.74
Cost of removing 1 ton of material, pounds	2.48

EXPERIMENTS ON THE ESCAPE OF STEAM THROUGH ORIFICES.

[A paper read before the International Engineering Congress at Glasgow, by M. RATEAU, Paris, France.]

The calculation of steam turbines depends upon the knowledge of the laws which determine the escape of steam through converging or converging-diverging orifices. In order to verify exactly the formulas for the escape of steam, the author undertook, in 1895–'96, at St. Etienne, a series of experiments on this subject, according to a method which gives the greatest possible precision. A short indication of these experiments has been given in the report on steam turbines which the author had the honor to present last year at the International Congress of Applied Mechanics in Paris. But at this time he had not yet completed all the calculations of the results of his experiments,

whereas, now he is able to give an account of the results. They differ a little from those the author provisionally announced at the Congress of 1900.

Those investigators who experimented before and since the author, namely, Minary and Résal in 1861, Peabody and Kunhard in 1890, Parenty in 1891, Miller and Read in 1895, and Rosenheim in 1900, have all used the same method, which consists of condensing in a surface condenser the steam which escapes by the orifice for a sufficiently long period, and then weighing the condensed water. But this method, beyond being very laborious, cannot give great precision, because in the first place it is very difficult to keep constant the initial steam-pressure P, during the whole of the experiments, and the steam, being never absolutely dry, the water which it carries with it is weighed with the condensed water, so that the results found must be generally overestimated.

The author therefore proposed to remove these causes of error so as to obtain exact results within two-thousandths, and to use besides sufficiently large orifices to deliver up to more than 900 kilos (1,980 pounds) of steam per hour.

He has reached the desired result by condensing the steam in a stream of water with the use of an ejector-condenser, and by measuring the total yield of water and the initial and final temperatures of this stream. Thus he was able to make all the readings at the same moment, as soon as constant conditions were obtained; and each experiment did not last more than one or two minutes. It has been possible thus without much trouble to make more than 140 observations under the most varied conditions.

Fig. 1 represents diagrammatically the apparatus employed. A is the ejector-condenser which receives steam through the pipe B, and cold water by the pipe C. The hot water containing condensed steam escapes by the pipe D into the sheet-iron chamber E, where the air separates out; then it goes out through the converging orifice F at a pressure measured by the water gage $h\,h$.

The rise in temperature of the water is measured by the ther-

mometers *e* and f, graduated to twentieths of a degree, and previously calibrated in comparison with a Baudin thermometer.

The nozzle to be tested is placed within the pipe at *I*. It receives the vapor through the pipe *H*, 50 mm. (2 inches) diameter, and throws it into the large pipe *B* of 120 mm. (4.8 inches) diameter. The initial pressure *P* (à l'amont) was measured by one or other of the gages *a* or *b*. The resultant

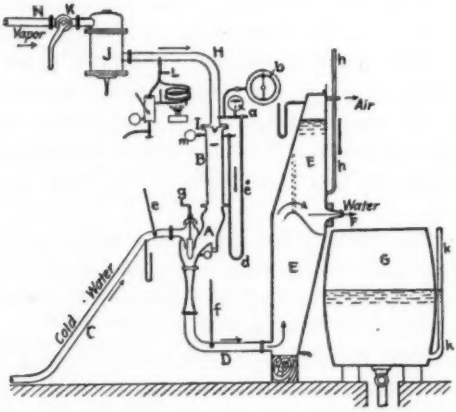


FIG. 1.—SKETCH OF APPARATUS FOR DETERMINING THE ESCAPE OF STEAM THROUGH ORIFICES.

pressure *p* (à l'aval) was measured by either the metallic pressure gage *m*, or the mercury gage *c d*.

The steam, arriving from the boiler by the pipe *N*, rushes with centrifugal force into the separator *J*, on account of the partial vacuum therein, and the small quantity remaining can be measured by the specially-arranged apparatus *L*.

The author was thus assured from the beginning of his experiments that the quantity of water passing the separator never exceeded 0.002 to 0.003, and as the error due to this method could not exceed a quarter of this amount, or an insignificant figure, he has neglected it.

The pressure before passing the nozzle could be regulated at

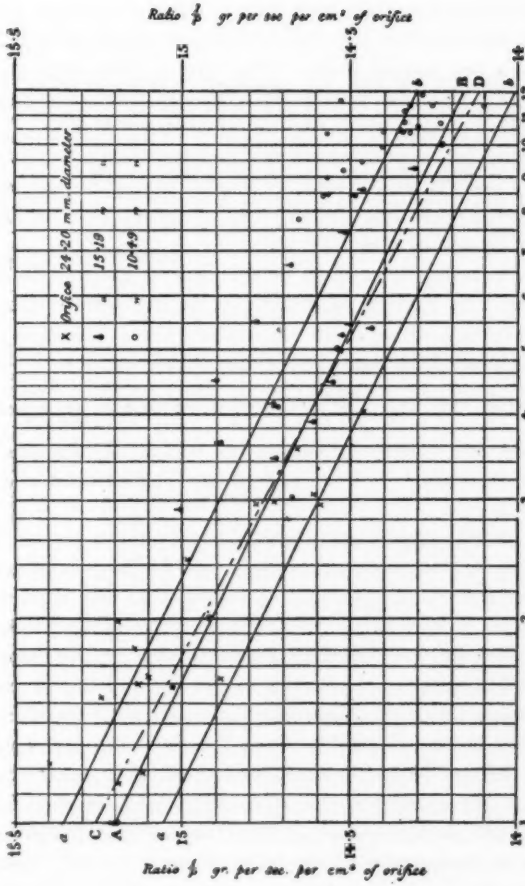


FIG. 2.—DIAGRAM ILLUSTRATING EXPERIMENTS ON ESCAPE OF STEAM THROUGH CONVERGING ORIFICES.

will by means of the cock K; a special valve, actuated by the crank g, enabled the pressure p (aval) to be fixed at any desired amount above the lowest pressure caused by the ejector-condenser. The author has thus been able to operate through a long range of pressures, from 0.12 to 12 kilos per square inch (0.22 to 26.4 pounds per square inch). The rate of flow through the water orifice F had been previously measured with great care by means of the barrel G graduated along the tube $K K$.

The author has experimented successfully upon a thin-walled orifice, and upon three converging nozzles having respectively a diameter at the narrowest part of 10.49, 15.19 and 24.20 millimeters (0.41, 0.59 and 0.95 inch).

Without entering into detail of the figures involved in these calculations, Fig. 2 gives in graphic form the results obtained with converging orifices, in all cases where the subsequent pressure p (aval) was less than 0.58 of the initial pressure P. The points indicate the ratio $\frac{I}{P}$ rate of consumption in grammes per second and per square centimeter of orifice, at the absolute pressure P (d'amont) in kilos per square centimeter for different values of P.

There are fifty-nine results which approximate to the theoretical straight line $A B$, calculated from Regnault's tables by the thermo-dynamical formula, assuming that the mechanical equivalent of heat is equal to 425 kilos (774 foot-pounds per B. T. U.) per calorie. The differences do not usually exceed 2 per cent. The mean of the results gives a figure 0.007 in excess, when compared with the theoretical calculation. This difference may be due to the displacement of the thermometer zeros (of 0.1 to 0.2 degree) during the course of the trials. It will be observed that this would not exceed 0.0035, if one assumed for the theoretical calculation a value 428 for the mechanical equivalent E, which is now admitted; for the formula of the speed of escape includes $\sqrt{2 g E}$ as a factor.

The scale of ordinates in the figure is contorted on account of the method of recording small differences. To show clearly the value of the differences, straight lines $a b$ and $a' b'$ have

been drawn on Fig. 2. These differ from the theoretical line by 1 per cent. more or less respectively. The line $C\,D$ corresponds to Grosshof's formula,

$$I = 15.26\ P^{0.9696}.$$

The correspondence between the theory and the practice is satisfactory. It is the same when the subsequent pressure p (aval) exceeds 0.58 P, in which case the consumption of steam depends on the two pressures p and P simultaneously, whilst the consumption depends on P only if p is less than 0.58 P.

In the latter case the consumption may be very exactly represented by the formula

$$I = P\,(15.20 - 0.96 \log P),$$

I being the consumption in grammes per second and per square centimeter of orifice, and P the initial pressure in kilos per square centimeter.

SOME PECULIARITIES OF STEEL.

In view of the present predominance of steel as a material of construction, and the exceedingly satisfactory way in which it behaves in general, it is somewhat curious to look back and note the distrust with which it was regarded by engineers of the last generation. When Sir Henry Bessemer suggested the use of steel for rails, a prominent engineer remarked that those who wished might use steel, but that personally he was not desirous of being indicted for manslaughter. The good qualities of the material were, however, gradually recognized, but at the same time there were periodically expressions of alarm at certain mysterious failures, of which at the present time we hear little or nothing. In one case we remember a steel-girder bridge was being built. A flange plate had been riveted on one evening, and on starting work next morning was found cracked across the center. At a later date still, some consternation was caused by the publication of a report by Mr. Maginis on the failure of a

boiler, the steel plates of which, after successfully passing Lloyd's tests, and being worked up without difficulty, cracked spontaneously after about two and one-half years' work. Largely in consequence of incidents of this nature engineers realized that it was insufficient to specify the chemical composition of steel, or even the physical tests which it must pass, but that attention must also be paid to methods of manufacture. This course occasioned strong protests from the steelmakers, who claimed that they should be allowed a free hand in operating their furnaces or mills, and that all the engineer had a right to demand was a steel capable of passing certain physical tests.

To a limited degree there was, and is, force in this contention. An analysis of some of the earlier steel rails, which had an excellent record, often discloses a composition which nowadays would certainly lead to the rejection of the metal, whatever its showing in the matter of physical tests. On the other hand, some of the heavy section rails used of late years have worn badly, although from a chemical point of view the metal was hardly capable of improvement. To a certain extent this defect in the wear of heavy steel rails has been met by increasing the percentage of carbon, but it is now generally admitted that the real remedy is to be found in finishing the rails at the lower temperature. This is the more important, in that the greater the quantity of non-ferrous constituents, the lower is the temperature at which the working of the metal should be completed, so that, from this point of view, the increase in the carbon tends to aggravate the difficulty. The curious fashion in which the critical temperatures of steel are affected by increasing the carbon content is capitally shown in a series of cooling curves illustrating a paper by M. Léon Lévy, published in the second volume of the French commission on the testing of the materials of construction. With steel containing 0.12 per cent. of carbon, three critical points are observed, the most marked corresponding to a temperature of 827.5 degrees centigrade. As the carbon increases, the three points gradually approach each other, and finally, with steels containing 0.80 per cent. of carbon, coalesce, the corresponding temperature being about 665 degrees centi-

grade, which is not greatly different from the temperature of recalescence in the milder qualities.

M. Osmond has pointed out that the quality of structural steel is really a function of three variables, viz: its chemical composition, its structure, and its freedom from initial stresses. All of these variables may differ materially even in bars rolled from a single ingot. Experiment shows that whilst the ingot is solidifying, the carbon, sulphur and phosphorus tend to concentrate in the center of the upper third of the ingot. Indeed, a content of phosphorus, on the average but 0.06 for the whole ingot, may, through segregation, be five times this figure in parts. The structure of a steel depends mainly on its treatment from the ingot up to the finished bar. Much light has been thrown on this matter by the microscopic examination of the polished and etched surfaces of the metal, whilst the knowledge of the properties of solutions worked out in other departments of science have permitted of some explanation being given of the peculiarities of structure found. Mere heat treatment is alone sufficient to considerably alter the structure of a bar. To cite a case brought forward by Mr. Kreuzpointner, a bar of .4 per cent. carbon-steel was cut into four pieces. One of these, tested in its original condition, showed a tensile strength of 103,000 pounds per square inch with an elongation of 15 per cent. By suitable heat treatment of a second piece of the bar, a steel was obtained showing a tensile strength of 87,000 pounds and an elongation of 35 per cent. in 2 inches. A third piece, heated differently, gave a tensile strength of 84,000 pounds, with an elongation of 22 per cent.; whilst the fourth piece, annealed at a high temperature, and "soaked" for 2½ hours, had a tensile strength of 80,000 pounds and an elongation of 20 per cent. in 2 inches. A microscopic study of etched sections showed corresponding changes in the structure of the metal. The "soaked" in particular had a large, coarse grain, and clearly showed the pernicious effect of the treatment to which it had been subjected. Similarly, the high quality of the Krupp armor is generally understood to be due to a peculiar heat treatment. As for initial stresses, they can, of course, be relieved by annealing; though there is a danger of, at the

same time, altering the structure of the metal for the worse, unless the process is carried out with judgment.

These facts are now pretty well known, and the engineer is seldom much troubled about the quality of his materials since most steel works are now in a position to supply an article of uniform and excellent quality. In fact, the burden of responsibility has largely been transferred to the shoulders of the steelmaker, since by careful inspection and tests his customer can make sure of getting the class of material he requires. Possibly the steelmaker is worried too much in this regard, since specifications for steel sometimes differ only enough in chemical composition to cause trouble in the mill, whilst the finished product is practically the same. In other cases excellent steel has been rejected as failing to comply with the physical requirements, whereas the whole trouble arose from its being tested too soon after rolling, a certain time being needed for the molecules to settle down after the violent disturbances to which they have been subjected.

It is probable that some of the early Bessemer steel was quite equal in quality to any of the mild steel since made, but this success was attained by the use of expensive and selected ores and fuels. The boast of the modern metallurgist is that out of very unpromising raw material he is able to produce an article that leaves little to be desired in either quality or price. This success has not been attained without many failures, and much groping in the dark as to their origin. It is only within the last few years that any clue has been obtained to a working theory of steel. Unfortunately, the manufacturer cannot wait to supply his market till physicists have completed their theories on the nature of its product, and of the intimate effect of the various processes to which it is subjected. Did he do so, he might save the cost of many expensive failures, but would infallibly lose his customers. Hence, at the outset he is bound to confine himself to the use of certain materials and certain processes which experience has proved to be satisfactory. Only as scientific knowledge slowly accumulates is he able to depart from his rule-of-

thumb procedure, and thus be in a position to utilize cheaper sources of supply.

Owing to the larger percentage of non-ferrous materials present in tool steel, the difficulties due to segregation and the like are much greater than in the case of the milder structural qualities. We thus find that makers of this class of steel are still dependent upon the use of high-priced ores, all attempts to use the cheaper raw materials having so far resulted in failure. Probably, as our knowledge of metallurgy increases, this difficulty will be overcome. As matters stand, however, this is far from being the case, and we find in a recent issue of the "Chemical News" a warning by Mr. Sergius Kern against the open-hearth high-carbon steel, which is sometimes now dishonestly sold as crucible tool steel, and which gives distinctly poor results when used for cutting instruments. Mr. Kern states that analysis will generally disclose the open-hearth origin of a tool steel which has proved unsatisfactory. The content of manganese is much larger than it should be, and the silicon generally lower than it is in crucible steel.—"Engineering."

THE EDISON STORAGE BATTERY.

In the form of cell of the new Edison storage battery patented some months ago, it will be recalled, the oxidizable element and the depolarizer consisted of finely divided iron and an oxide of nickel (or cobalt), respectively, both elements being preferably mixed with flake graphite to increase their permeability to the alkali hydroxide solution. In the forms now disclosed the oxidizable metal is zinc, the depolarizer an oxide either of copper or of nickel, and the electrolyte an alkali metal zincate in solution. These combinations are not unfamiliar, but the cells have not, hitherto, been considered as reversible, and the conditions under which they are rendered so are in the highest degree interesting.

If it be attempted to reverse a cell of the usual zinc—alkali hydroxide—copper oxide type, it will be found that the copper passes in part into solution as the so-called "cuprite," and that

the zinc is deposited in the form of a loose sponge. Mr. Edison states that if certain precautions be observed in the preparation of the copper oxide, its tendency to solution in the alkaline electrolyte may be overcome, and he considers an essential feature of this preparation to be an extremely fine subdivision of

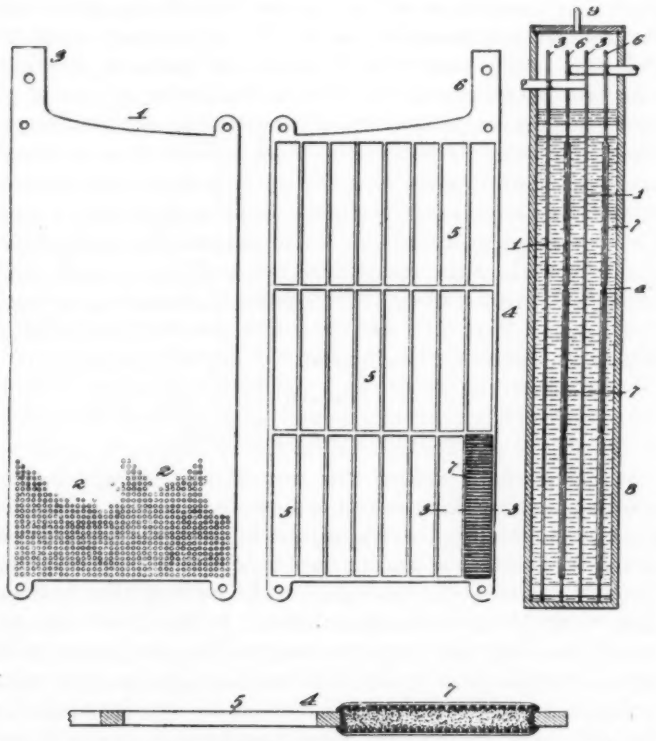


FIG. 1.—EDISON STORAGE BATTERY.

the copper. To secure this, pure carbonate of copper is reduced by hydrogen at the lowest possible temperature, molded into the desired form, oxidized by heat to the black oxide, CuO, and finally electrolytically reduced to the metallic state. So prepared,

it is oxidized in charging the battery to the red oxide Cu_2O, but shows no tendency to pass into solution. It is difficult, indeed, to believe that this remarkable effect is properly attributed to the state of minute subdivision; if so, the fact is unique in chemistry.

The second difficulty—the deposition of spongy zinc—is overcome by the simple expedient of using as a base for the electro-deposit a thin multi-perforated sheet of magnesium. If it be assumed that the tendency of zinc to deposit in sponge form is due to the partial oxidation of the precipitated metal, then it is readily apparent that the nature of the support may exert a con-

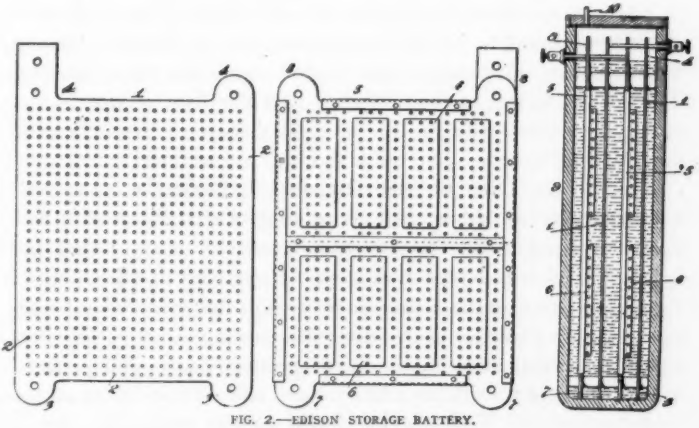


FIG. 2.—EDISON STORAGE BATTERY.

trolling influence on the character of the deposit, and that magnesium, being electro-positive to zinc and entirely unattacked by the caustic alkali, can give rise to no local action, and therefore to no oxidation due to this cause. This is the explanation of the inventor. It is not free from chemical difficulties, for other means may be employed to prevent local action, and yet these have not proven efficient in suppressing the formation of sponge; but the essential commercial point—the fact—seems to have been sufficiently established by Mr. Edison's experimental work.

In the accompanying illustrations, Fig. 2 represents a plan view

of the magnesium support on which the zinc is plated during the charging, a similar view of the plate for carrying the negative element, and a vertical section through a cell formed of four elements. In Fig. 1 are represented similar views of another form of cell, showing a plan view of one of the magnesium supports on which the zinc is plated during the charging operation, a a similar support for the depolarizing material, a section of the latter on an enlarged scale and a section through a four-element cell.—"Electrical World and Engineer."

CITY OF TRENTON EXPLOSION.

The jury appointed to inquire into the cause of the explosion of the locomotive boiler on the steamship *City of Trenton*, "owing to conflicting testimony," were unable to fix the responsibility. The verdict stated, as their opinion, that the disaster, which cost twenty-four lives, was due to the crown sheet of the boiler becoming overheated. The other findings are of interest:

That the form, material and design of the boiler was in accordance with the printed regulations as contained in Form 2101 and approved by the Secretary of the Treasury, in 1901; that the inspection of this boiler had been as complete as the limited force employed by the Government in this territory would permit; that we consider the number of men employed by the Government for this work in this district entirely too inadequate to secure the best results, and recommend that the attention of the Secretary of the Treasury be drawn to the matter so that a remedy be provided as soon as possible; that we do not approve of the operation of a boiler of such a design and location with a bridge wall located in the fire box in the manner employed in this boiler, especially when using forced blast on the fires; that if such construction is approved and used, we recommend that the fusible plug should be placed in the center of the corner sheet transversely and directly over the bridge wall; that the requirements of the United States Government rules concerning fusible plugs were not complied with.

The jury, composed of prominent designers and builders of

boilers, was engaged in the examination of the exploded boiler for nearly a week. It was believed that the exact cause of the explosion would be clearly defined, and that the responsibility would be placed where it belonged. There is a concensus of opinion in local shipping circles that an injustice has therefore been done the builders of this boiler. Negligence was the cause of the explosion. This was demonstrated by a private examination made of the boiler at Neafie & Levy's shipyard after it was recovered from the Delaware river. The investigation, which was made merely in the interests of science, was conducted by S. C. Custar, a well-known boiler expert, and by Robert H. Rogers, formerly master mechanic of the Pittsburg division of the Baltimore & Ohio Railroad, and member of its board to investigate accidents to locomotive boilers. They found the outer shell of the boiler intact, the tubes and radial stays in good condition, and no rupture evident in the water legs. The crown sheet was torn directly downward and away from the front of the tube sheet.

While there were some minor defects to criticize in the arrangement of the stays there was nothing evident to warrant a disaster so extensive. The damaged crown sheet, however, told its own story as graphically as though it were endowed with speech. When the surface of its metal was cleaned the latter was found to be a well-tempered blue. No better testimony as to its condition just previous to the explosion could possibly have been obtained. The crown sheet was so hot that when, after its collapse the boiler was blown into the Delaware river, contact with the cold water cooled the sheet almost instantly and it held the color as well as a chisel tempered by a blacksmith. An additional proof of low water was afforded in the fact that the check valve on the starboard boiler, which remained in the boat undamaged, was closed, while that on the one in question was wide open. Every effort was being made after the discovery of low water to force in an additional supply as soon as possible. If this had been a locomotive boiler on the road it would have been a perplexing case. The overheated crown sheet would then have cooled of its own accord and very slowly. In

this instance, however, it was thrown into the cold river and its condition instantaneously recorded. There is great dissatisfaction over the verdict, but in all probability there will be no further investigation.—" Marine Review."

THE NAVY DEPARTMENT has approved the recommendation of the Bureau of Equipment that the voltage of all electrical appliances for ships of the United States Navy will hereafter be 125 volts. The standard voltage for the past 13 years has been 80 volts, that figure having been decided upon by a board of officers in 1888, the present chief of the Bureau of Equipment having been a member of that board. At that time the generators supplied current for incandescent lights and search lights only, and the voltage adopted was a compromise or mean between the voltages used for search lights and incandescent lights. This change to a commercial voltage will facilitate obtaining the necessary apparatus for the electrical outfit and the increase in voltage will reduce the weight of wiring, conduit, etc., used in installations with a corresponding reduction in the first cost for the electric plant.—"Army and Navy Register."

THE STEEL FLOATING DRYDOCK built by the Maryland Steel Co. for the Government, and intended for use at Algiers, La., started on its long journey on October 15. It was towed by three tugs and carried a crew of 18 men. It was thought that 30 days would be required to make the trip, but much better speed was made than had been expected. The dock arrived at Algiers on November 6.

THE BRITISH NAVAL DEPARTMENT has authorized the construction of a sixth submarine boat. It differs from the preceding vessels, which are of the Holland pattern, and also from the French type, in many respects. It is not quite such a fast traveler as the French boats, but it will be able to rise and to descend with greater facility and celerity. A torpedo tube is

placed at the extreme forward end of the boat, while four 18-inch Whitehead torpedoes are to be carried. The gear is also being arranged so that the torpedoes may be discharged while the boat is either stationary or running at any speed submerged or awash. The boat is to be fitted with a horizontal rudder in addition to the vertical pattern. Automatic means also determine the angle of diving or ascending, and also prevent the possibility of descending to excessive depths. The men who have been selected for manning these submarine vessels are to receive double pay. The first boat, which is nearly ready, is to be attached to the first-class battleship *Formidable* for service in the Mediterranean.—"Scientific American."

NEW DOCKS AT GIBRALTAR.

According to the "Journal of the Royal United Service Institution," there are three new docks under construction at Gibraltar, of which the largest, divisible into two, will be 850 feet long, the second 550 feet, and the third 450 feet, with a width of 120 feet, and a depth of 35 feet on the sill at low water in each case. A length of 100 yards of the parade ground by the south mole has been cut off, and by banking out the sea the necessary space for the docks has been secured. According to information obtained a few months ago, only about a quarter of the largest dock, where the parade ground formerly was, had been excavated so far, but the concrete backing for the masonry was already in its place. The excavation of the smallest dock, though commenced only about eight months ago, was already down to the lowest level, but it will take another five or six months before the dam cutting off the sea from the intended outer extremity of the docks is completed, after which the intermediate dock and outer portion of the large dock will be taken in hand. A space of foreshore, about 500 yards by 150 yards, on the outside of the docks, along the foot of the old water line of the fortification wall, has been filled in, and on this strongly-built sheds for machine shops and repairing establishments have been commenced; while torpedo-boat slips, in continuation of this

filled-in shore, extending to the ragged staff landing place, are rapidly approaching completion.

THE "Engineer," in speaking of the *Formidable*, remarks that the *Formidable* was to have been flagship, but the Admiral will not have her because, it is said, he objects to her inward-turning screws. Such screws are disliked by many naval officers, who hold that they make getting out of harbor very difficult. The point, however, is a moot one—no very clear data are available. Some, or all, of the *Diadem* class have such screws, and as they are the unhandiest vessels ever conceived by man, the screws have come in for a share of the blame.

EXPERIMENTS with a new submarine boat, invented by a Brazilian naval officer, have been carried out, says a Reuter telegram from Rio Janeiro, before the President of the Republic, with excellent results. The boat immerses itself and returns to the surface with great ease, keeping a horizontal position all the time. The government has decided to have a larger boat built for the final trials.

ANOTHER NAVAL DISASTER is reported from Copenhagen on October 1, on which date the Danish gunboat *Moen*, while at gun-practice with Prisant shells, foundered to the eastward of the Middle Ground. The crew of thirty-five men was saved. The *Moen* was an iron gunboat of 356 tons displacement. She was 111 feet long, had 28 feet 10 inches beam, and was built at Copenhagen, in 1875.

TABLE

TORPEDO BOATS, U. S. NAV

COMPILED BY A. B. LEP. ME

CYLINDERS.—C = Compound; T = Triple; Q = Quadruple; H = Horizontal; V = Vertical;

MAIN AIR PUMP.—S = Single acting; D = Double acting; H = Horizontal; V = Vertical; A

NOTE.—Designed data on upper line. Tri

Number.	Name.	Displacement.	Length on load-water line.	Beam.	Mean draught.	Speed.	Cylinders. Type.	H.P.	I.P.	2dI.P.	L.P.	Stroke.	Revolutions.	I.H.P. main engines, air, circulating pumps.	Steam pressure.	Vacuum.	Air pressure.	Boilers. Type.	Total grate surface.	Total heating surface.
1	*Cushing*	105	138-9	14-3	4-10⅛	...	VQ	11¼	16	22½	(22½)	15	...	1,600	250	...	...	2 Thornycroft.	76.6	4,75
		...	...	...	...	22.5	...	...	...	...	(22½)	...	370	1,720	245	24	2.7	.....	...	...
2	*Ericsson*	120	149-7	15-6	4-10½	24	VQ	11½	16	21½	30	16	...	1,800	250	...	...	2 Thornycroft.	85	4,69
		...	...	...	...	22.36	...	...	...	...	...	...	361.5	1,557	...	...	...	.....	...	...
3	*Foote*	142	160	16-0⅜	5	24.5	VT	12	19½	...	(22)	16	412	2,000	250	...	...	2 Mosher.	95	5,26
		138.3	...	...	...	24.53	...	...	...	...	(22)	...	395.7	2,400	...	22	4.18	.....	...	...
4	*Rodgers*	142	160	16-0⅜	5-5	24.5	VT	12	19½	...	(22)	16	412	2,000	250	...	...	2 Mosher.	95	5,26
		...	...	...	...	22.3	...	...	...	...	(22)	...	366	...	232	23	...	.....	...	...
5	*Winslow*	142	160	16-0⅜	5	24.5	VT	12	19½	...	(22)	16	412	2,000	250	...	...	2 Mosher.	95	5,26
		138	...	...	5-3½	24.8	...	...	...	...	(22)	...	394.4	...	...	23	...	.....	...	...
6	*Porter*	165	175	17-8½	4-8	26	VT	16	22½	...	(25)	16	395	3,200	250	...	...	3 Mod. Normand.	160.6	8,28
		...	...	...	...	28.6	...	...	...	...	(25)	...	389.5	...	196	23¼	...	.....	...	...
7	*Dupont*	165	175	17-8½	4-8	26	VT	16	22½	...	(25)	16	395	3,200	250	...	...	3 Mod. Normand.	160.6	8,28
		...	...	...	...	...	...	...	...	...	(25)	...	...	...	...	...	...	.....	...	...
8	*Rowan*	182	170	17	5-11¼	26	VT	14½	23	...	(25½)	18	395	3,200	250	...	...	3 Mosher.	143.4	7,89
		184.25	...	...	...	27.07	...	...	...	...	(25½)	...	368	...	232	27.7	2.9	.....	...	...
9	*Dahlgren*	146.5	147	16-4½	4-7½	30	VT	17.22	24.78	...	37.37	21	340	4,200	230	...	...	2 Normand.	118.75	5.55
		...	...	...	...	29.75	...	...	...	...	...	...	314.4	...	226	26.8	...	.....	...	...
10	*T. A. M. Craven*	146.5	147	16-4½	4-7½	30	VT	17.22	24.78	...	37.37	21	340	4,200	230	...	...	2 Normand.	118.75	5.55
		132.72	...	...	4-3⅛	...	...	...	...	...	...	...	322	...	224	23.5	5	.....	...	...
11	*Farragut*	279	213-6	20-7⅜	6	30	VT	20	29	...	(30)	18	400	5,600	240	...	...	3 Thornycroft.	196	9,91
		236.3	...	...	6-5½	30.62	...	...	...	...	(30)	...	427.6	...	222.5	25	4.25	.....	...	...
12	*Davis*	154	146	15-4	5-10	22.5	VT	11½	19	...	(22½)	15	395	1,750	250	...	...	2 Thornycroft.	88	4,76
		126	...	...	5-3⅜	23.4	...	...	...	...	(22½)	...	382	...	212	23	2	.....	...	...
13	*Fox*	154	146	15-4	5-10	22.5	VT	11½	19	...	(22½)	15	395	1,750	250	...	...	2 Thornycroft.	88	4,76
		123	...	...	5-2	23.13	...	...	...	...	(22½)	...	380.4	...	202.5	25	2	.....	...	...
14	*Morris*	104.75	138-3	15-6	4-3	23	VT	12½	18	...	25	13⅛	410	1,750	225	...	...	2 Normand.	80	4,00
		98	...	...	...	...	...	...	...	...	...	...	451.9	...	195.5	25	1.75	.....	...	...
15	*Talbot*	46.5	99-6	12-6	3-9⅛	20.25	VT	12½	18	...	25	13⅛	400	850	225	...	...	1 Normand.	38	1,87
		45.75	...	...	...	21.15	...	...	...	...	...	...	437.9	...	199.8	23.4	3.3	.....	...	...
16	*Gwin*	45.78	99-6	12-6	3-9½	20.25	VT	12½	18	...	25	13⅛	400	850	225	...	...	1 Normand.	38	1,87
		44.5	...	...	...	20.88	...	...	...	...	...	...	442.3	...	206	24.6	2.94	.....	...	...
17	*Mackenzie*	65	99-3	12-9½	4-3	20	VT	12	19½	...	(22)	16	330	850	250	...	...	2 Thornycroft.	40	2,16
		...	...	...	...	...	...	...	...	...	(22)	...	...	...	...	...	...	.....	...	...
18	*McKee*	65	99-3	12-9½	4-8⅛	20	VT	12	19½	...	(22)	16	350	850	250	...	...	2 Thornycroft	40	2,29
		...	...	...	...	19 82	...	...	...	...	(22)	...	307	...	215	25.5	3	.....	...	...
19	*Stringham*	340	225	22	6-6	30	VT	22	32½	...	(34)	18	400	7,200	240	...	...	4 Thornycroft.	252	16,02
		...	...	...	...	...	...	...	...	...	(34)	...	...	...	...	...	...	.....	...	...
20	*Goldsborough*	247.5	194-8	20-5	5	30	VT	19⅜	31⅜	...	(35⅜)	20	360	5,850	250	...	...	3 Thornycroft.	216	13,50
		...	...	...	...	...	...	...	...	...	(35⅜)	...	...	...	...	...	...	.....	...	...
21	*Bailey*	235	205	19-2⅞	6	30	VT	20	30½	...	(32)	18	400	5,600	243	...	...	4 Seabury.	225	13,20
		...	...	...	...	...	...	...	...	...	(32)	...	370	...	...	...	...	.....	...	...
22	*Bagley*	167	157	17	4-7½	28	VT	17.22	24.78	...	37.37	21	320	4,200	230	...	...	2 Normand.	118.75	5.55
		...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	.....	...	...
23	*Barney*	167	157	17	4-7½	28	VT	17.22	24.78	...	37.37	21	320	4,200	230	...	...	2 Normand.	118.75	5.55
		...	...	...	...	26.16	...	...	...	...	...	...	290.8	...	200	20.3	6.04	.....	...	...
24	*Biddle*	167	157	17	4-7⅛	28	VT	17.22	24.78	...	37.37	21	320	4,200	230	...	...	2 Normand.	118.75	5.55
		...	...	...	...	28.6	...	...	...	...	...	...	307.3	...	219 5	22	4.8	.....	...	...
25	*Blakely*	166	175-1½	17-8⅜	4-8	26	VT	14	22	...	(25½)	18	350	3,000	250	...	...	3 Normand.	150	7.57
		...	...	...	...	...	...	...	...	...	(25½)	...	...	...	...	...	...	.....	...	...
26	*DeLong*	166	175-1½	17-8 7/16	4-8	26	VT	14	22	...	(25½)	18	350	3,000	250	...	...	3 Normand.	150	7.57
		...	...	...	...	...	...	...	...	...	(25½)	...	...	...	...	...	...	.....	...	...
27	*Nicholson*	174	174-6	17	4-6	26	VT	18	27	...	(27½)	18	350	3,500	250	...	...	3 Mosher.	157.5	8,40
		...	...	...	...	...	...	...	...	...	(27½)	...	...	...	...	...	...	.....	...	...
28	*O'Brien*	174	174-6	17	4-6	26	VT	18	27	...	(27½)	18	350	3,500	250	...	...	3 Mosher.	157.5	8,40
		...	...	...	...	...	...	...	...	...	(27½)	...	...	...	...	...	...	.....	...	...
29	*Shubrick*	165	175	17-6	4-8	26	VT	14	22	...	(25½)	18	350	3,000	250	...	...	3 Thornycroft.	137	7,54
		185	...	...	...	26 2	...	...	...	...	(25½)	...	365 8	...	256.5	23.5	2.83	.....	...	...
30	*Stockton*	165	175	17-6	4-8	26	VT	14	22½	...	(25½)	18	350	3,000	250	...	...	3 Thornycroft.	137	7,54
		208	...	...	...	25.79	...	...	...	...	(25½)	...	356¼ 8	3,775	230	22.2	3	.....	...	...
31	*Thornton*	165	175	17-6	4-8	26	VT	14	22	...	(25½)	18	350	3,000	250	...	...	3 Thornycroft.	137	7,54
		...	...	...	...	...	...	...	...	...	(25½)	...	...	...	...	...	...	.....	...	...
32	*Tingey*	165	175	17-6	4-8	26	VT	14	22	...	(25½)	18	350	3,000	250	...	...	3 Thornycroft.	137	7,54
		...	...	...	...	...	...	...	...	...	(25½)	...	...	...	...	...	...	.....	...	...
33	*Wilkes*	165	175	17-7⅛	4-8	26	VT	14	22	...	(25½)	18	350	3,000	250	...	...	3 Seabury.	137	7,80
		...	...	...	...	...	...	...	...	...	(25½)	...	...	...	...	...	...	.....	...	...
34	*Somers*	150	149-3⅛	17-6	5-10½	23	VQ	17	24	33⅝	42½	18⅛	...	...	...	...	...	1 Locomotive.	47	2,24
		...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	.....	...	...
35	*Manly*	30	60-8	9-5	2-10⅜	17	...	...	...	...	...	...	...	...	...	...	...	.....	...	...
		...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	.....	...	...
36	*Bainbridge*	420	245	23-7½	6-6	28	VT	20½	32	...	(38)	22	327	8,000	300	...	...	4 Thornycroft.	315	17,76
		...	...	...	...	...	...	...	...	...	(38)	...	...	...	...	...	...	.....	...	...
37	*Barry*	420	245	23-7½	6-6	28	VT	20½	32	...	(38)	22	327	8,000	300	...	...	4 Thornycroft.	315	17,76
		...	...	...	...	...	...	...	...	...	(38)	...	...	...	...	...	...	.....	...	...
38	*Chauncey*	420	245	23-7½	6-6	28	VT	20½	32	...	(38)	22	327	8,000	300	...	...	4 Thornycroft.	315	17,76
		...	...	...	...	...	...	...	...	...	(38)	...	...	...	...	...	...	.....	...	...
39	*Dale*	420	245	23-7½	6-6	28	VT	20½	32	...	(38)	22	327	8,000	300	...	...	4 Thornycroft.	315	17,76
		...	...	...	...	...	...	...	...	...	(38)	...	...	...	...	...	...	.....	...	...
40	*Decatur*	420	245	23-7½	6-6	28	VT,	20½	32	...	(38)	22	327	8,000	300	...	...	4 Thornycroft.	315	17,76
		...	...	...	...	...	...	...	...	...	(38)	...	...	...	...	...	...	.....	...	...
41	*Hopkins*	408	244	24-6	6	29	VT	22	32½	...	(34)	18	400	7,200	240	...	...	4 Thornycroft.	294	17,61
		...	...	...	...	...	...	...	...	...	(34)	...	...	...	...	...	...	.....	...	...
42	*Hull*	408	244	24-6	6	29	VT	22	32½	...	(34)	18	400	7,200	240	...	...	4 Thornycroft.	294	17,61
		...	...	...	...	...	...	...	...	...	(34)	...	...	...	...	...	...	.....	...	...
43	*Lawrence*	400	240-10	22-3	6-1½	28	VT	22	31	...	(34)	20	360	8,400	250	...	...	4 Fore River.	304	18,11
		...	...	...	...	...	...	...	...	...	(34)	...	...	...	...	...	...	.....	...	...
44	*Macdonough*	400	240-10	22-3	6-1½	28	VT	22	31	...	(34)	20	360	8,400	250	...	...	4 Fore River.	304	18,11
		...	...	...	...	...	...	...	...	...	(34)	...	...	...	...	...	...	.....	...	...

BLE I.

NAVY.—GENERAL DATA.

LEP. MESNY, MARCH, 1901.

1; V=Vertical; B = Back acting; D = Directing acting; I = Inclined.

V=Vertical; A = Direct connected; I = Independent; C = Crank; B = Central inlet.

upper line. Trial data on lower line.

lers.			Condenser.		Main air pump.							Main circulating pump.			Propeller.				Date.	Remarks.
	Total grate surface.	Total heating surface.	Cooling surface. M=Main. A=Aux.		Type.	Number.	Stroke.	One pump. Water. No. cyls.	Water. Dia.	Steam. No. cyls.	Steam. Dia.	Number.	Diameter of runner.	Dia. cyl. Stroke.	Number.	Diameter.	Mean pitch.	Helicoidal area of one screw.		
	76.6	4,750	M	1,052	IVS	1	5	3	10	2	$3\frac{1}{2}\times3\frac{1}{2}$ / 5	1	$13\frac{1}{2}$	$\frac{4}{4}$	2	4-3	8-4½	9.35	1889	.....
	85	4,698	M	1,379	HAS	2	3	1	14	..	...	1	$14\frac{1}{2}$	$\frac{5}{8\frac{1}{2}}$	2	4-9	7-8	8.5	Mar., 1890	.....
	95	5,260	M	1,602	HABD	2	5	2	$5\frac{1}{2}$	..	...	2	15	$\frac{4}{8}$	2	5-2	7-10	9.68	1890	.....
	95	5,260	M	1,602	HABD	2	5	2	$5\frac{1}{2}$	..	...	2	15	$\frac{4}{8}$	2	5-3	7-9½	9.67	1894	.....
	95	5,260	M	1,602	HABD	2	5	2	$5\frac{1}{2}$	..	...	2	15	$\frac{4}{8}$	2	5-3	7-9½	9.67	1894	.....
d.	160.6	8,288	M	2,326	IVS	2	4	3	10	2	4×4 / 5	2	$13\frac{1}{2}$	$\frac{4}{4}$	2	5-4	8-8½	10.75	1894	.....
d.	160.6	8,288	M	2,326	IVS	2	4	3	10	2	4×4 / 5	2	$13\frac{1}{2}$	$\frac{4}{4}$	2	5-4	8-8½	10.3	June 25, 1897	.....
	143.4	7,890	M	2,599	HABD	2	6	2	$6\frac{1}{2}$	..	...	2	19	$\frac{4\frac{1}{2}}{6}$	2	6	9-5½	13.26	1894	.....
	118.75	5,552	M	2,366	AVS	2	4.28	1	13.19	..	...	2	9	$\frac{1\frac{3}{4}}{2\frac{1}{2}}$	2	6-5	11-5½	13.63	Mar. 22, 1898	.....
	118.75	5,552	M	2,366	AVS	2	4.28	1	13.19	..	...	2	9	$\frac{1\frac{3}{4}}{2\frac{1}{2}}$	2	6-5	11-6½	13.63	1894	.....
	196	9,912	M	2,813	AVS	2	$3\frac{1}{2}$	1	20	..	...	1	26	$\frac{5}{4}$	2	6-9	8-9	12	Dec. 1, 1897	.....
	88	4,763	M	1,400	HABD	2	$4\frac{1}{2}$	2	$5\frac{1}{2}$	..	...	1	16	$\frac{5}{8\frac{1}{2}}$	2	4-10½	7-3	8.5	1895	.....
	88	4,763	M	1,400	HABD	2	$4\frac{1}{2}$	2	$5\frac{1}{2}$	..	...	1	16	$\frac{5}{8\frac{1}{2}}$	2	4-10½	7-3	8.5	Feb. 10, 1897	.....
	80	4,004	M	1,195	IVS	2	4	3	10	2	4×4 / 5	1	14	$\frac{4}{4}$	2	4-8	6-2½	6.9	1895	.....
	38	1,870	M	600	IVS	1	4	3	10	2	$3\frac{1}{2}\times3\frac{1}{2}$ / 5	1	$11\frac{7}{8}$	$\frac{3\frac{1}{2}}{8\frac{1}{2}}$	1	4-8	6	6.9	1895	.....
	38	1,870	M	600	IVS	1	4	3	10	2	$3\frac{1}{2}\times3\frac{1}{2}$ / 5	1	$11\frac{7}{8}$	$\frac{3\frac{1}{2}}{8\frac{1}{2}}$	1	4-8	6-3	6.9	Feb. 10, 1897	.....
	40	2,168	M	685	HABD	1	5	2	$5\frac{1}{2}$	..	...	1	15	$\frac{4}{8}$	1	5-3	6-7	11	1895	.....
	40	2,294	M	677	HABD	1	5	2	$5\frac{1}{2}$	..	...	1	15	$\frac{4}{8}$	1	5-7	7-2	11 4	1895	.....
	252	16,020	M	5,406	AVS	2	5	1	21	..	...	1	$18\frac{1}{2}$	$\frac{3\times3}{4}$	2	7-9	9-6	18.14	Jan. 6, 1899	.....
	216	13,500	M	4,000	AVS	2	$3\frac{1}{2}$	1	$20\frac{1}{2}$	..	...	1	20	$\frac{6}{5}$	2	7-4	9-11½	33 9	1896	.....
	225	13,200	M	3,937	IVS	2	6	4	12	2	5×10 / 6	2	...	$\frac{5}{5}$	2	6-10	9-1½	16.4	Oct. 27, 1899	.....
	118.75	5,552	M	2,366	AVS	2	4 28	1	13.19	..	...	2	18	$\frac{4}{8}$	2	7-6	10-9½	14.75	1896	.....
	118.75	5,552	M	2,366	AVS	2	4.28	1	13.19	..	...	2	18	$\frac{4}{8}$	2	7-6	10-9½	14.75	Feb. 21, 1900	.....
	118.75	5,552	M	2,366	AVS	2	4.28	1	13.19	..	...	2	18	$\frac{4}{8}$	2	7-6	10-9½	14.75	1896	.....
	150	7,575	M	2,482	...	..	...	..	...	..	...	2	18	$\frac{4}{8}$	2	5-6	8-11	11 52	Dec. 2, 1898	.....
	150	7,575	M	2,482	...	..	...	..	...	..	...	2	18	$\frac{4}{8}$	2	5-6	8-11	11.52	1896	.....
	157.5	8,406	M	2,959	AVBD	2	4	1	14	..	...	2	19	$\frac{6}{8}$	2	6-5	9-4	12.9	Nov. 24, 1898	.....
	157.5	8,406	M	2,959	AVBD	2	4	1	14	..	...	2	19	$\frac{6}{8}$	2	6-5	9-4	12 9	1896	.....
	137	7,548	M	2,501	VABD	2	6	1	11	..	...	2	18	$\frac{4}{8}$	2	5-8	9	10.3	Feb. 18, 1899	.....
	137	7,548	M	2,501	VABD	2	6	1	11	..	...	2	18	$\frac{4}{8}$	2	5-8	9	10.3	1896	.....
	137	7,548	M	2,501	VABD	2	6	1	11	..	...	2	18	$\frac{4}{8}$	2	5-8	8-11½	10.2	Apr. 17, 1898	.....
	137	7,548	M	2,480	VABD	2	6	1	11	..	...	2	18	$\frac{4}{8}$	2	6-3	9-4½	14.37	1896	.....
	137	7,800	M	2,481.5	VABD	2	6	1	11	..	...	2	18	$\frac{5}{8}$	2	...	...	...	May 2, 1898	.....
	47	2,242	M		...	..	...	..	...	..	...	..	...	..	1	...	...	...	1897	Purchased abroad
	...	...	..		...	..	...	..	...	..	...	..	...	..	1	...	...	...	.....	Purchased abroad
	315	17,768	M	6,940	VABD	4	6	1	12	..	...	2	20	$\frac{4\frac{1}{2}}{5}$	2	7-3	10-10½	19.75	1897	.....
	315	17,768	M	6,940	VABD	4	6	1	12	..	...	2	20	$\frac{4\frac{1}{2}}{5}$	2	7-3	10-10½	19.75	Apr. 25, 1901	.....
	315	17,768	M	6,940	VABD	4	6	1	12	..	...	2	20	$\frac{4\frac{1}{2}}{5}$	2	7-3	10-10½	19 75	1898	.....
	315	17,768	M	6,960	VABD	4	6	1	12	..	...	2	20	$\frac{4\frac{1}{2}}{5}$	2	7-10	10-3	21	Oct. 20, 1900	.....
	315	17,768	M	6,960	VABD	4	6	1	12	..	...	2	20	$\frac{4\frac{1}{2}}{5}$	2	7-10	10-3	21	1898	.....
	294	17,612	M	5,992	VAS	2	5	1	21	..	...	2	$18\frac{1}{2}$	$\frac{3\times3}{4}$	2	7-9	9-6	18.14	1898	.....
	294	17,612	M	5,992	VAS	2	5	1	21	..	...	2	$18\frac{1}{2}$	$\frac{3\times3}{4}$	2	7-9	9-6	18.14	Jul 2, 1901	.....
	304	18,117	M	6,992	VAS	1	6	3	12	2	4×4 / 4	2	20	$\frac{4\frac{1}{2}}{4}$	2	7-3	12	17.66	1898	.....
	304	18,117	M	6,992	VAS	1	6	3	12	2	4×4 / 4	2	20	$\frac{4\frac{1}{2}}{4}$	2	7-3	12	17.66	1898	.....

TABLE I.

TORPEDO BOATS, U. S. NAVY.—

COMPILED BY A. B. LEP. MESNY, MA

CYLINDERS.—C = Compound; T = Triple; Q = Quadruple; H = Horizontal; V = Vertical; B = Back actin

MAIN AIR PUMP.—S = Single acting; D = Double acting; H = Horizontal; V = Vertical; A = Direct conn

NOTE.—Designed data on upper line. Trial data on lowe

Name.	Displacement.	Length on load-water line.	Beam.	Mean draught.	Speed.	Type.	Cylinders.				Stroke.	Revolutions.	I. H. P. main engines, air, circulating pumps.	Steam pressure.	Vacuum.	Air pressure.	Boilers.			Condenser.	
							H.P.	I.P.	2dI.P.	L.P.							Type.	Total grate surface.	Total heating surface.	Cooling surface. M=Main. A=Aux.	
...shing	105	138-9	14-3	4-10½	...	VQ	11½	16	22½	(22½ / 22½)	15	...	1,600	250	...	...	2 Thornycroft.	76.6	4,750	M	1,052
	...	...	...	...	22.5	...	...	...	...	...	...	...	370	1,720	245	24	2.7	.....	...	..	...
...icsson	120	149-7	15-6	4-10½	24	VQ	11½	16	21½	30	16	...	1,800	250	...	...	2 Thornycroft.	85	4,698	M	1,379
	...	...	...	...	22.36	...	...	...	...	...	...	...	361.5	1,557	...	...	.....	...	...	..	...
...te	142	160	16-0¾	5	24.5	VT	12	19½	...	(22 / 22)	16	412	2,000	250	...	...	2 Mosher.	95	5,260	M	1,602
	138.3	...	...	...	24.53	...	...	...	...	...	...	395.7	2,400	...	22	4.18	.....	...	...	..	...
...dgers	142	160	16-0¾	5-5	24.5	VT	12	19½	...	(22 / 22)	16	412	2,000	250	...	...	2 Mosher.	95	5,260	M	1,602
	...	...	...	...	22.3	...	...	...	...	...	...	366	...	232	23	...	.....	...	...	..	...
...nslow	142	160	16-0¾	5	24.5	VT	12	19½	...	(22 / 22)	16	412	2,000	250	...	...	2 Mosher.	95	5,260	M	1,602
	138	...	...	5-3½	24.8	...	...	...	...	...	...	394.4	...	...	23	...	.....	...	...	..	...
...rter	165	175	17-8½	4-8	26	VT	16	22½	...	(25 / 25)	16	395	3,200	250	...	...	3 Mod. Normand.	160.6	8,288	M	2,326
	...	...	...	...	28.6	...	...	...	...	...	...	389.5	...	196	23½	...	.....	...	...	..	...
...pont	165	175	17-8½	4-8	26	VT	16	22½	...	(25 / 25)	16	395	3,200	250	...	...	3 Mod. Normand	160.6	8,288	M	2,326
	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	.....	...	...	..	...
...wan	182	170	17	5-11½	26	VT	14½	23	...	(25⅝ / 25⅝)	18	395	3,200	250	...	...	3 Mosher.	143.4	7,890	M	2,599
	184.25	...	...	...	27.07	...	...	...	...	...	...	368	...	232	27.7	2.9	.....	...	...	..	...
...hlgren	146.5	147	16-4½	4-7½	30	VT	17.22	24.78	...	37.37	21	340	4,200	230	...	...	2 Normand.	118.75	5,552	M	2,366
	...	...	...	...	29.75	...	...	...	...	...	...	314.4	...	226	26.8	...	.....	...	...	..	...
	A. M. Craven.	146.5	147	16-4½	4-7½	30	VT	17.22	24.78	...	37.37	21	340	4,200	230	...	...	2 Normand.	118.75	5,552	M	2,366
	132.72	...	...	4-3½	...	...	...	...	...	...	...	322	...	224	23.5	5	.....	...	...	..	...
...rragut	279	213-6	20-7½	6	30	VT	20	29	...	(30 / 30)	18	400	5,600	240	...	...	3 Thornycroft.	196	9,912	M	2,813
	236.3	...	...	6-5 1/16	30.62	...	...	...	...	...	...	427.6	...	222.5	25	4.25	.....	...	...	..	...
...wis	154	146	15-4	5-10	22.5	VT	11½	19	...	(22½ / 22½)	15	395	1,750	250	...	...	2 Thornycroft.	88	4,763	M	1,400
	126	...	...	5-3½	23.4	...	...	...	...	...	...	382	...	212	23	2	.....	...	...	..	...
...x	154	146	15-4	5-10	22.5	VT	11½	19	...	(22½ / 22½)	15	395	1,750	250	...	...	2 Thornycroft.	88	4,763	M	1,400
	123	...	...	5-2	23.13	...	...	...	...	...	...	380.4	...	202.5	25	2	.....	...	...	..	...
...orris	104.75	138-3	15-6	4-3	23	VT	12½	18	...	25	13½	410	1,750	225	...	...	2 Normand.	80	4,004	M	1,195
	98	...	...	...	...	...	...	...	...	...	...	451.9	...	195.5	25	1.75	.....	...	...	..	...
...albot	46.5	99-6	12-6	3-9½	20.25	VT	12½	18	...	25	13½	400	850	225	...	...	1 Normand.	38	1,870	M	600
	45.75	...	...	...	21.15	...	...	...	...	...	...	437.9	...	199.8	23.4	3.3	.....	...	...	..	...
...win	45.78	99-6	12-6	3-9½	20.25	VT	12½	18	...	25	13½	400	850	225	...	...	1 Normand.	38	1,870	M	600
	44.5	...	...	...	20.88	...	...	...	...	...	...	442.3	...	206	24.6	2.94	.....	...	...	..	...
...ackenzie	65	99-3	12-9½	4-3	20	VT	12	19½	...	(22 / 22)	16	350	850	250	...	...	2 Thornycroft.	40	2,168	M	685
	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	.....	...	...	..	...
...cKee	65	99-3	12-9½	4-8⅜	20	VT	12	19½	...	(22 / 22)	16	350	850	250	...	...	2 Thornycroft	40	2,294	M	677
	...	...	...	...	19 82	...	...	...	...	...	...	...	...	215	25.5	3	.....	...	...	..	...
...ringham	340	223	22	6-6	30	VT	22	32½	...	(34 / 34)	18	400	7,200	240	...	...	4 Thornycroft.	252	16,020	M	5,406
	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	.....	...	...	..	...
...oldsborough	247.5	194-8	20-5	5	30	VT	19½	31½	...	(35½ / 35½)	20	360	5,850	250	...	...	3 Thornycroft.	216	13,500	M	4,000
	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	.....	...	...	..	...
...ailey	235	205	19-2½	6	30	VT	20	30½	...	(32 / 32)	18	400	5,600	245	...	...	4 Seabury.	225	13,200	M	3,937
	...	...	...	...	...	...	...	...	...	...	...	370	...	...	...	...	.....	...	...	..	...
...agley	167	157	17	4-7½	28	VT	17.22	24.78	...	37.37	21	320	4,200	230	...	...	2 Normand.	118.75	5,552	M	2,366
	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	.....	...	...	..	...
...arney	167	157	17	4-7½	28	VT	17.22	24.78	...	37.37	21	320	4,200	230	...	...	2 Normand.	118.75	5,552	M	2,366
	...	...	...	...	26.16	...	...	...	...	...	...	290.8	...	200	20.3	6.04	.....	...	...	..	...
...iddle	167	157	17	4-7½	28	VT	17.22	24.78	...	37.37	21	320	4,200	230	...	...	2 Normand.	118.75	5,552	M	2,366
	...	...	...	...	28.6	...	...	...	...	...	...	307.3	...	219 5	22	4.8	.....	...	...	..	...
...lahely	166	175-1½	17-8½	4-8	26	VT	14	22	...	(25½ / 25½)	18	350	3,000	250	...	...	3 Normand.	150	7,575	M	2,482
	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	.....	...	...	..	...
...DeLong	166	175-1½	17-8 7/16	4-8	26	VT	14	22	...	(25½ / 25½)	18	350	3,000	250	...	...	3 Normand.	150	7,575	M	2,482
	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	.....	...	...	..	...
...icholson	174	174-6	17	4-6	26	VT	18	27	...	(27½ / 27½)	18	350	3,500	250	...	...	3 Mosher.	157.5	8,406	M	2,959
	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	.....	...	...	..	...
	O'Brien	174	174-6	17	4-6	26	VT	18	27	...	(27½ / 27½)	18	350	3,500	250	...	...	3 Mosher.	157.5	8,406	M	2,959
	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	.....	...	...	..	...
...hubrick	165	175	17-6	4-8	26	VT	14	22	...	(25½ / 25½)	18	350	3,000	250	...	...	3 Thornycroft.	137	7,548	M	2,501
	185	...	...	...	26 2	...	...	...	...	...	...	365 8	...	256.5	23.5	2.83	.....	...	...	..	...
...tockton	165	175	17-6	4-8	26	VT	14	22½	...	(25½ / 25½)	18	350	3,000	250	...	...	3 Thornycroft.	137	7,548	M	2,501
	208	...	...	...	25.79	...	...	...	...	...	...	356½	3,975	230	22.2	3	.....	...	...	..	...
...Thornton	165	175	17-6	4-8	26	VT	14	22	...	(25½ / 25½)	18	350	3,000	250	...	...	3 Thornycroft.	137	7,548	M	2,501
	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	.....	...	...	..	...
...Tingey	165	175	17-6	4-8	26	VT	14	22	...	(25½ / 25½)	18	350	3,000	250	...	...	3 Thornycroft.	137	7,548	M	2,480
	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	.....	...	...	..	...
...Wilkes	165	175	17-7½	4-8	26	VT	14	22	...	(25½ / 25½)	18	350	3,000	250	...	...	3 Seabury.	137	7,800	M	2,481.5
	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	.....	...	...	..	...
...omers	150	149-3½	17-6	5-10½	23	VQ	17	24	33 3/32	42½	18½	...	...	...	...	...	1 Locomotive.	47	2,242	M	...
	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	.....	...	...	..	...
...Manly	30	60-8	9-5	2-10½	17	...	...	...	...	...	...	...	...	...	...	...	.....	...	...	..	...
	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	.....	...	...	..	...
...Bainbridge	420	245	23-7½	6-6	28	VT	20½	32	...	(38 / 38)	22	327	8,000	300	...	...	4 Thornycroft.	315	17,768	M	6,940
	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	.....	...	...	..	...
...Barry	420	245	23-7½	6-6	28	VT	20½	32	...	(38 / 38)	22	327	8,000	300	...	...	4 Thornycroft.	315	17,768	M	6,940
	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	.....	...	...	..	...
...Chauncey	420	245	23-7½	6-6	28	VT	20½	32	...	(38 / 38)	22	327	8,000	300	...	...	4 Thornycroft.	315	17,768	M	6,940
	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	.....	...	...	..	...
...Dale	420	245	23-7½	6-6	28	VT	20½	32	...	(38 / 38)	22	327	8,000	300	...	...	4 Thornycroft.	315	17,768	M	6,960
	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	.....	...	...	..	...
...Decatur	420	245	23-7½	6-6	28	VT	20½	32	...	(38 / 38)	22	327	8,000	300	...	...	4 Thornycroft.	315	17,768	M	6,960
	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	.....	...	...	..	...
...Hopkins	408	244	24-6	6	29	VT	22	32½	...	(34 / 34)	18	400	7,200	240	...	...	4 Thornycroft.	294	17,612	M	5,992
	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	.....	...	...	..	...
...Hull	408	244	24-6	6	29	VT	22	32½	...	(34 / 34)	18	400	7,200	240	...	...	4 Thornycroft.	294	17,612	M	5,992
	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	.....	...	...	..	...
...Lawrence	400	240-10	22-3	6-1½	28	VT	22	31	...	(34 / 34)	20	360	8,400	250	...	...	4 Fore River.	304	18,117	M	6,992
	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	.....	...	...	..	...
...Macdonough	400	240-10	22-3	6-1½	28	VT	22	31	...	(34 / 34)	20	360	8,400	250	...	...	4 Fore River.	304	18,117	M	6,992

I.

VY.—GENERAL DATA.

SNY, MARCH, 1901.

B = Back acting; D = Directing acting; I = Inclined.

= Direct connected; I = Independent; C = Crank; B = Central inlet.

al data on lower line.

	Condenser.		Main air pump.							Main circulating pump.			Propeller.				Date.	Remarks.	Number.
		Cooling surface.				One pump.													
						Water.		Steam.											
	M=Main. A=Aux.		Type.	Number.	Stroke.	No. cyls.	Dia.	No. cyls.	Dia.	Number.	Diameter of runner.	Dia. cyl. / Stroke.	Number.	Diameter.	Mean pitch.	Helicoidal area of one screw.			
0	M	1,052	IVS	1	5	3	10	2	$3\frac{1}{2}\times3\frac{1}{2}$ / 6	1	$13\frac{3}{4}$	$\frac{4}{4}$	2	4-3	8-4½	9.35	1889	.....	1
																	Mar., 1890	.....	
8	M	1,379	HAS	2	3	1	14			1	$14\frac{3}{4}$	$\frac{5}{5\frac{1}{2}}$	2	4-9	7-8	8.5	1890	.....	2
																	1894	.....	
0	M	1,602	HABD	2	5	2	5½			2	15	$\frac{4}{5\frac{1}{2}}$	2	5-2	7-10	9.68	1894	.....	3
																	June 25, 1897	.....	
0	M	1,602	HABD	2	5	2	5½			2	15	$\frac{4}{5\frac{1}{2}}$	2	5-3	7-9½	9.67	1894	.....	4
																	Mar. 22, 1898	.....	
0	M	1,602	HABD	2	5	2	5½			2	15	$\frac{4}{5\frac{1}{2}}$	2	5-3	7-9½	9.67	1894	.....	5
																	Dec. 1, 1897	.....	
8	M	2,326	IVS	2	4	3	10	2	4×4 / 6	2	$13\frac{3}{4}$	$\frac{4}{4}$	2	5-4	8-8½	10.75	1895	.....	6
																	Feb. 10, 1897	.....	
8	M	2,326	IVS	2	4	3	10	2	4×4 / 6	2	$13\frac{3}{4}$	$\frac{4}{4}$	2	5-4	8-8½	10.3	1895	.....	7
																	.....	.....	
0	M	2,599	HABD	2	6	2	6½			2	19	$\frac{4\frac{1}{2}}{5\frac{1}{2}}$	2	6	9-5½	13.26	1895	.....	8
																	Jan. 6, 1899	.....	
2	M	2,366	AVS	2	4.28	1	13.19			2	9	$\frac{1\frac{1}{2}}{2\frac{1}{2}}$	2	6-5	11-5½	13.63	1896	.....	9
																	Oct. 27, 1899	.....	
2	M	2,366	AVS	2	4.28	1	13.19			2	9	$\frac{1\frac{1}{2}}{2\frac{1}{2}}$	2	6-5	11-6½	13.63	1896	.....	10
																	Feb. 21, 1900	.....	
2	M	2,813	AVS	2	3½	1	20			1	26	$\frac{5}{4}$	2	6-9	8-9	12	1896	.....	11
																	Dec. 2, 1898	.....	
3	M	1,400	HABD	2	4½	2	5½			1	16	$\frac{5}{3\frac{1}{2}}$	2	4-10½	7-3	8.5	1896	.....	12
																	Nov. 24, 1898	.....	
3	M	1,400	HABD	2	4½	2	5½			1	16	$\frac{5}{3\frac{1}{2}}$	2	4-10½	7-3	8.5	1896	.....	13
																	Feb. 18, 1899	.....	
4	M	1,195	IVS	2	4	3	10	2	4×4 / 6	1	14	$\frac{4}{4}$	2	4-8	6-2½	6.9	1896	.....	14
																	Apr. 17, 1898	.....	
0	M	600	IVS	1	4	3	10	2	$3\frac{1}{2}\times3\frac{1}{2}$ / 6	1	$11\frac{3}{4}$	$\frac{3\frac{1}{2}}{3\frac{1}{2}}$	1	4-8	6	6.9	1896	.....	15
																	Mar. 3, 1898	.....	
0	M	600	IVS	1	4	3	10	2	$3\frac{1}{2}\times3\frac{1}{2}$ / 6	1	$11\frac{3}{4}$	$\frac{3\frac{1}{2}}{3\frac{1}{2}}$	1	4-8	6-3	6.9	1896	.....	16
																	Mar. 3, 1898	.....	
8	M	685	HABD	1	5	2	5½			1	15	$\frac{4}{5}$	1	5-3	6-7	11	1896	.....	17
																	.....	.....	
4	M	677	HABD	1	5	2	5½			1	15	$\frac{4}{5}$	1	5-7	7-2	11 4	1896	.....	18
																	May 2, 1898	.....	
0	M	5,406	AVS	2	5	1	21			1	$18\frac{3}{4}$	$\frac{3\times3}{4}$	2	7-9	9-6	18.14	1897	.....	19
																	.....	.....	
0	M	4,000	AVS	2	3½	1	20½			1	20	$\frac{6}{6}$	2	7-4	9-11½	33 9	1897	.....	20
																	.....	.....	
0	M	3,937	IVS	2	6	4	12	2	5×10 / 6	2	...	$\frac{5}{5}$	2	6-10	9-1½	16.4	1897	.....	21
																	Apr. 25, 1901	.....	
2	M	2,366	AVS	2	4.28	1	13.19			2	18	$\frac{4}{5}$	2	7-6	10-9½	14.75	1898	.....	22
																	.....	.....	
2	M	2,366	AVS	2	4.28	1	13.19			2	18	$\frac{4}{5}$	2	7-6	10-9½	14.75	1898	.....	23
																	Oct. 20, 1900	.....	
2	M	2,366	AVS	2	4.28	1	13.19			2	18	$\frac{4}{5}$	2	7-6	10-9½	14.75	1898	.....	24
																	July 2, 1901	.....	
5	M	2,482	...	...	...	...	...	...	...	2	18	$\frac{4}{5}$	2	5-6	8-11	11 52	1898	.....	25
																	.....	.....	
5	M	2,482	...	...	...	...	...	...	...	2	18	$\frac{4}{5}$	2	5-6	8-11	11.52	1898	.....	26
																	.....	.....	
6	M	2,959	AVBD	2	4	1	14			2	19	$\frac{6}{6}$	2	6-5	9-4	12.9	1898	.....	27
																	.....	.....	
6	M	2,959	AVBD	2	4	1	14			2	19	$\frac{6}{6}$	2	6-5	9-4	12 9	1898	.....	28
																	.....	.....	
8	M	2,501	VABD	2	6	1	11			2	18	$\frac{4}{5}$	2	5-8	9	10.3	1898	.....	29
																	Apr. 2, 1901	.....	
8	M	2,501	VABD	2	6	1	11			2	18	$\frac{4}{5}$	2	5-8	9	10.3	1898	.....	30
																	Nov. 28, 1900	.....	
8	M	2,501	VABD	2	6	1	11			2	18	$\frac{4}{5}$	2	5-8	9	10.3	1898	.....	31
																	.....	.....	
8	M	2,480	VABD	2	6	1	11			2	18	$\frac{4}{5}$	2	6-3	9-4½	14.37	1898	.....	32
																	.....	.....	
0	M	2,481.5	VABD	2	6	1	11			2	18	$\frac{5}{5}$	2	...	...	...	1898	.....	33
																	.....	.....	
2	M	...	...	...	...	...	...	...	...	...	...	...	1	...	...	...	.....	Purchased abroad.	34
																	.....	.....	
													1	...	...	...	.....	Purchased abroad.	35
																	.....	.....	
8	M	6,940	VABD	4	6	1	12			2	20	$\frac{4\frac{1}{2}}{5}$	2	7-3	10-10½	19.75	1898	.....	36
																	.....	.....	
8	M	6,940	VABD	4	6	1	12			2	20	$\frac{4\frac{1}{2}}{5}$	2	7-3	10-10½	19.75	1898	.....	37
																	.....	.....	
8	M	6,940	VABD	4	6	1	12			2	20	$\frac{4\frac{1}{2}}{5}$	2	7-3	10-10½	19 75	1898	.....	38
																	.....	.....	
8	M	6,960	VABD	4	6	1	12			2	20	$\frac{4\frac{1}{2}}{5}$	2	7-10	10-3	21	1898	.....	39
																	.....	.....	
8	M	6,960	VABD	4	6	1	12			2	20	$\frac{4\frac{1}{2}}{5}$	2	7-10	10-3	21	1898	.....	40
																	.....	.....	
2	M	5,992	VAS	2	5	1	21			2	$18\frac{3}{4}$	$\frac{3\times3}{4}$	2	7-9	9-6	18.14	1898	.....	41
																	.....	.....	
2	M	5,992	VAS	2	5	1	21			2	$18\frac{3}{4}$	$\frac{3\times3}{4}$	2	7-9	9-6	18.14	1898	.....	42
																	.....	.....	
7	M	6,992	VAS	1	6	3	12	2	4×4 / 4	2	20	$\frac{4\frac{1}{2}}{4}$	2	7-3	12	17.66	1898	.....	43
																	.....	.....	
7	M	6,992	VAS	1	6	3	12	2	4×4 / 4	2	20	$\frac{4\frac{1}{2}}{4}$	2	7-3	12	17.66	1898	.....	44

NOTE.—Designed draft on upper line.

Number.	Name.	Displacement.	Length on load-water line.	Beam.	Mean draught.	Speed.	Cylinders. Type.	H.P.	I.P.	2dI.P.	L.P.	Stroke.	Revolutions.	I.H.P. main engines, air, circulating pumps.	Steam pressure.	Vacuum.	Air pressure.	Boilers. Type.	Total grate surface.	Total heating
1	*Cushing*	105	138-9	14-3	4-10⅛	...	VQ	11¼	16		22½	15	...	1,600	250	...	...	2 Thornycroft.	76.6	4
		...	...	...	...	22.5		...	...	...	22½	...	370	1,720	245	24	2.7	.....	...	
2	*Ericsson*	120	149-7	15-6	4-10⅛	24	VQ	11½	16		21½	16	...	1,800	250	...	...	2 Thornycroft.	85	4
		...	...	...	...	22.36		...	...	...	...	...	361.5	1,557	...	...	...	.....	...	
3	*Foote*	142	160	16-0¾	5	24.5	VT	12	19½	...	22	16	412	2,000	250	...	...	2 Mosher.	95	5
		138.3	...	...	...	24.53		...	...	...	22	...	395.7	2,400	...	22	4.18	.....	...	
4	*Rodgers.*	142	160	16-0¾	5-5	24.5	VT	12	19½	...	22	16	412	2,000	250	...	...	2 Mosher.	95	5
		...	...	...	...	22.3		...	...	...	22	...	366	...	232	23	...	.....	...	
5	*Winslow*	142	160	16-0¾	5	24.5	VT	12	19½	...	22	16	412	2,000	250	...	...	2 Mosher.	95	5
		138	...	...	5-3⅛	24.8		...	...	...	22	...	394.4	...	...	23	...	.....	...	
6	*Porter*	165	175	17-8¼	4-8	26	VT	16	22½	...	25	16	395	3,200	250	...	...	3 Mod. Normand.	160.6	8
		...	...	...	...	28.6		...	...	...	25	...	389.5	...	196	23¼	...	.....	...	
7	*Dupont*	165	175	17-8¼	4-8	26	VT	16	22½	...	25	16	395	3,200	250	...	...	3 Mod. Normand	160.6	8
		...	...	...	...	...		...	...	...	25	...	...	...	...	...	...	.....	...	
8	*Rowan*	182	170	17	5-11¼	26	VT	14½	23	...	25½	18	395	3,200	250	...	...	3 Mosher.	143.4	7
		184.25	...	...	...	27.07		...	...	...	25½	...	368	...	232	27.7	2.9	.....	...	
9	*Dahlgren*	146.5	147	16-4½	4-7½	30	VT	17.22	24.78	...	37.37	21	340	4,200	230	...	...	2 Normand.	118.75	5
		...	...	...	...	29.75		...	...	...	...	...	314.4	...	226	26.8	...	.....	...	
10	*T. A. M. Craven*	146.5	147	16-4½	4-7½	30	VT	17.22	24.78	...	37.37	21	340	4,200	230	...	...	2 Normand.	118.75	5
		132.72	...	...	4-3⅜	...		...	...	...	...	...	322	...	224	23.5	5	.....	...	
11	*Farragut*	279	213-6	20-7¾	6	30	VT	20	29	...	30	18	400	5,600	240	...	...	3 Thornycroft.	196	9
		236.3	...	...	6-5 1/16	30.62		...	...	...	30	...	427.6	...	222.5	25	4.25	.....	...	
12	*Davis*	154	146	15-4	5-10	22.5	VT	11½	19	...	22½	15	395	1,750	250	...	...	2 Thornycroft.	88	4
		126	...	...	5-3⅜	23.4		...	...	...	22½	...	382	...	212	23	2	.....	...	
13	*Fox*	154	146	15-4	5-10	22.5	VT	11½	19	...	22½	15	395	1,750	250	...	...	2 Thornycroft.	88	4
		123	...	...	5-2	23.13		...	...	...	22½	...	380.4	...	202.5	25	2	.....	...	
14	*Morris*	104.75	138-3	15-6	4-3	23	VT	12½	18	...	25	13½	410	1,750	225	...	...	2 Normand.	80	4
		98	...	...	...	...		...	...	...	...	...	451.9	...	195.5	25	1.75	.....	...	
15	*Talbot*	46.5	99-6	12-6	3-9½	20.25	VT	12½	18	...	25	13½	400	850	225	..	...	1 Normand.	38	1
		45.75	...	...	...	21.15		...	...	...	...	...	437.9	...	199.8	23.4	3.3	.....	...	
16	*Gwin*	45.78	99-6	12-6	3-9½	20.25	VT	12½	18	...	25	13½	400	850	225	...	...	1 Normand.	38	1
		44.5	...	...	...	20.88		...	...	...	...	...	442.3	...	206	24.6	2.94	.....	...	
17	*Mackenzie*	65	99-3	12-9½	4-3	20	VT	12	19½	...	22	16	350	850	250	...	...	2 Thornycroft.	40	2
		...	...	...	...	...		...	...	...	22	...	...	...	...	...	...	.....	...	
18	*McKee*	65	99-3	12-9½	4-8½	20	VT	12	19½	...	22	16	350	850	250	...	...	2 Thornycroft	40	2
		...	...	...	...	19 82		...	...	...	22	...	307	...	215	25.5	3	.....	...	
19	*Stringham*	340	225	22	6-6	30	VT	22	32½	...	34	18	400	7,200	240	...	...	4 Thornycroft.	252	16
		...	...	...	...	...		...	...	...	34	...	...	...	...	...	...	.....	...	
20	*Goldsborough*	247.5	194-8	20-5	5	30	VT	19½	31½	...	35½	20	360	5,850	250	...	...	3 Thornycroft.	216	13
		...	...	...	...	...		...	...	...	35½	...	...	...	...	...	...	.....	...	
21	*Batley*	235	205	19-2⅛	6	30	VT	20	30½	...	32	18	400	5,600	245	...	...	4 Seabury.	225	13
		...	...	...	...	...		...	...	...	32	...	370	...	...	...	...	.....	...	
22	*Bagley*	167	157	17	4-7½	28	VT	17.22	24.78	...	37.37	21	320	4,200	230	...	...	2 Normand.	118.75	5
		...	...	...	...	...		...	...	...	...	...	...	...	...	...	...	.....	...	
23	*Barney*	167	157	17	4-7½	28	VT	17.22	24.78	...	37.37	21	320	4,200	230	...	...	2 Normand.	118.75	5
		...	...	...	...	26.16		...	...	...	...	...	290.8	...	200	20.3	6.04	.....	...	
24	*Biddle*	167	157	17	4-7½	28	VT	17.22	24.78	...	37.37	21	320	4,200	230	...	...	2 Normand.	118.75	5
		...	...	...	...	28.6		...	...	...	...	...	307.3	...	219 5	22	4.8	.....	...	
25	*Blakely*	166	175-1½	17-8¼	4-8	26	VT	14	22	...	25½	18	350	3,000	250	...	...	3 Normand.	150	7
		...	...	...	...	...		...	...	...	25½	...	...	...	...	...	...	.....	...	
26	*DeLong*	166	175-1½	17-8 1/16	4-8	26	VT	14	22	...	25½	18	350	3,000	250	...	...	3 Normand.	150	7
		...	...	...	...	...		...	...	...	25½	...	...	...	...	...	...	.....	...	
27	*Nicholson*	174	174-6	17	4-6	26	VT	18	27	...	27½	18	350	3,500	250	...	...	3 Mosher.	157.5	8
		...	...	...	...	...		...	...	...	27½	...	...	...	...	...	...	.....	...	
28	*O'Brien*	174	174-6	17	4-6	26	VT	18	27	...	27½	18	350	3,500	250	...	...	3 Mosher.	157.5	8
		...	...	...	...	...		...	...	...	27½	...	...	...	...	...	...	.....	...	
29	*Shubrick*	165	175	17-6	4-8	26	VT	14	22	...	25½	18	350	3,000	250	...	...	3 Thornycroft.	137	7
		185	...	...	...	26 2		...	...	...	25½	...	365 8	...	256.5	23.5	2.83	.....	...	
30	*Stockton*	165	175	17-6	4-8	26	VT	14	22½	...	25½	18	350	3,000	250	...	...	3 Thornycroft.	137	7
		202	...	...	...	25.79		...	...	...	25½	...	356½	3,275	230	22.2	3	.....	...	
31	*Thornton*	165	175	17-6	4-8	26	VT	14	22	...	25½	18	350	3,000	250	...	...	3 Thornycroft.	137	7
		...	...	...	...	...		...	...	...	25½	...	...	...	...	...	...	.....	...	
32	*Tingey*	165	175	17-6	4-8	26	VT	14	22	...	25½	18	350	3,000	250	...	...	3 Thornycroft.	137	7
		...	...	...	...	...		...	...	...	25½	...	...	...	...	...	...	.....	...	
33	*Wilkes*	165	175	17-7⅛	4-8	26	VT	14	22	...	25½	18	350	3,000	250	...	...	3 Seabury.	137	7
		...	...	...	...	...		...	...	...	25½	...	...	...	...	...	...	.....	...	
34	*Somers*	150	149-3⅛	17-6	5-10¼	23	VQ	17	24	...	33 3/32	18½	...	...	...	...	...	1 Locomotive.	47	2
		...	...	...	...	...		...	...	...	...	...	...	...	...	...	...	.....	...	
35	*Manly*	30	60-8	9-5	2-10½	17	...	...	...	...	...	...	...	...	...	...	...	.....	...	
		...	...	...	...	...		...	...	...	...	...	...	...	...	...	...	.....	...	
36	*Bainbridge*	420	245	23-7½	6-6	28	VT	20½	32	...	38	22	327	8,000	300	...	...	4 Thornycroft.	315	17
		...	...	...	...	...		...	...	...	38	...	...	...	...	...	...	.....	...	
37	*Barry*	420	245	23-7½	6-6	28	VT	20½	32	...	38	22	327	8,000	300	...	...	4 Thornycroft.	315	17
		...	...	...	...	...		...	...	...	38	...	...	...	...	...	...	.....	...	
38	*Chauncey*	420	245	23-7½	6-6	28	VT	20½	32	...	38	22	327	8,000	300	...	...	4 Thornycroft.	315	17
		...	...	...	...	...		...	...	...	38	...	...	...	...	...	...	.....	...	
39	*Dale*	420	245	23-7½	6-6	28	VT	20½	32	...	38	22	327	8,000	300	...	...	4 Thornycroft.	315	17
		...	...	...	...	...		...	...	...	38	...	...	...	...	...	...	.....	...	
40	*Decatur*	420	245	23-7½	6-6	28	VT	20½	32	...	38	22	327	8,000	300	...	...	4 Thornycroft.	315	17
		...	...	...	...	...		...	...	...	38	...	...	...	...	...	...	.....	...	
41	*Hopkins*	408	244	24-6	6	29	VT	22	32½	...	34	18	400	7,200	240	...	...	4 Thornycroft.	294	17
		...	...	...	...	...		...	...	...	34	...	...	...	...	...	...	.....	...	
42	*Hull*	408	244	24-6	6	29	VT	22	32½	...	34	18	400	7,200	240	...	...	4 Thornycroft.	294	17
		...	...	...	...	...		...	...	...	34	...	...	...	...	...	...	.....	...	
43	*Lawrence*	400	240-10	22-3	6-1½	28	VT	22	31	...	34	20	360	8,400	250	...	...	4 Fore River.	304	18
		...	...	...	...	...		...	...	...	34	...	...	...	...	...	...	.....	...	
44	*Macdonough*	400	240-10	22-3	6-1½	28	VT	22	31	...	34	20	360	8,400	250	...	...	4 Fore River.	304	18
		...	...	...	...	...		...	...	...	34	...	...	...	...	...	...	.....	...	
45	*Paul Jones*	420	245	23-7½	6-6	28	VT	20½	32	...	38	22	327	8,000	300	...	...	4 Thornycroft.	315	17
		...	...	...	...	...		...	...	...	38	...	...	...	...	...	...	.....	...	
46	*Perry*	420	245	23-7½	6-6	28	VT	20½	32	...	38	22	327	8,000	300	...	...	4 Thornycroft.	315	17
		...	...	...	...	...		...	...	...	38	...	...	...	...	...	...	.....	...	
47	*Preble*	420	245	23-7½	6-6	28	VT	20½	32	...	38	22	327	8,000	300	...	...	4 Thornycroft.	315	17
		...	...	...	...	...		...	...	...	38	...	...	...	...	...	...	.....	...	
48	*Stewart*	420	245	23-7½	6-6	28	VT	20½	32	...	38	22	327	8,000	300	...	...	4 Seabury.	315½	17
		...	...	...	...	...		...	...	...	38	...	...	...	...	...	...	.....	...	
49	*Truxtun*	433	248	23-3	6	28	VT	23	34	...	37	22	327	8,300	240	...	...	4 Thornycroft.	315	17
		...	...	...	...	...		...	...	...	37	...	...	...	...	...	...	.....	...	
50	*Whipple*	433	248	23-3	6	28	VT	23	34	...	37	22	327	8,300	240	...	...	4 Thornycroft.	315	17
		...	...	...	...	...		...	...	...	37	...	...	...	...	...	...	.....	...	
51	*Worden*	433	248	23-3	6	28	VT	23	34	...	37	22	327	8,300	240	...	...	4 Thornycroft.	315	17
		...	...	...	...	...		...	...	...	37	...	...	...	...	...	...	.....	...	

oilers.			Condenser.		Main air pump.						Main circulating pump.			Propeller.				Date.	Remarks
	Total grate surface.	Total heating surface.	Cooling surface. M=Main. A=Aux.		Type.	Number.	Stroke.	One pump. Water. No. cyls.	Water. Dia.	Steam. No. cyls.	Steam. Dia.	Number.	Diameter of runner.	Dia. cyl. / Stroke.	Number.	Diameter.	Mean pitch.	Helicoidal area of one screw.		
ft.	76.6	4,750	M	1,052	IVS	1	5	3	10	2	3½×3½ / 5	1	13¾	4 / 4	2	4-3	8-4½	9.35	1889	.....
ft.	85	4,698	M	1,379	HAS	2	3	1	14	..	...	1	14¾	3½ / 4	2	4-9	7-8	8.5	Mar., 1890	.....
	95	5,260	M	1,602	HABD	2	5	2	5½	..	...	2	15	3½ / 4	2	5-2	7-10	9.68	1890	.....
	95	5,260	M	1,602	HABD	2	5	2	5½	..	...	2	15	3½ / 4	2	5-3	7-9½	9.67	1894	.....
	95	5,260	M	1,602	HABD	2	5	2	5½	..	...	2	15	3½ / 4	2	5-3	7-9½	9.67	June 25, 1897	.....
and.	160.6	8,288	M	2,326	IVS	2	4	3	10	2	4×4 / 5	2	13¾	4 / 4	2	5-4	8-8½	10.75	Mar. 22, 1898	.....
and	160.6	8,288	M	2,326	IVS	2	4	3	10	2	4×4 / 5	2	13¾	4 / 4	2	5-4	8-8½	10.3	1894	.....
	143.4	7,890	M	2,599	HABD	2	6	2	6½	..	...	2	19	4½ / 4	2	6 ..	9-5½	13.26	Dec. 1, 1897	.....
.	118.75	5,552	M	2,366	AVS	2	4.28	1	13.19	..	...	2	9	3½ / 2⅞	2	6-5	11-5½	13.63	Feb. 10, 1897	.....
.	118.75	5,552	M	2,366	AVS	2	4.28	1	13.19	..	...	2	9	3½ / 2⅞	2	6-5	11-6½	13.63	1895	.....
ft.	196	9,912	M	2,813	AVS	2	3½	1	20	..	...	1	26	5 / 4	2	6-9	8-9	12	Jan. 6, 1899	.....
ft.	88	4,763	M	1,400	HABD	2	4½	2	5½	..	...	1	16	3½ / 3½	2	4-10½	7-3	8.5	1896	.....
ft.	88	4,763	M	1,400	HABD	2	4½	2	5½	..	...	1	16	3½ / 3½	2	4-10½	7-3	8.5	Oct. 27, 1899	.....
.	80	4,004	M	1,195	IVS	2	4	3	10	2	4×4 / 5	1	14	4 / 4	2	4-8	7-5½ / 6-2½	6.9	1896	.....
.	38	1,870	M	600	IVS	1	4	3	10	2	3½×3½ / 5	1	11¾	3½ / 3½	1	4-8	6	6.9	Feb. 21, 1900	.....
.	38	1,870	M	600	IVS	1	4	3	10	2	3½×3½ / 5	1	11¾	3½ / 3½	1	4-8	6-3	6.9	1896	.....
ft.	40	2,168	M	685	HABD	1	5	2	5½	..	...	1	15	4 / 3	1	5-3	6-7	11	Dec. 2, 1898	.....
ft	40	2,294	M	677	HABD	1	5	2	5½	..	...	1	15	4 / 3	1	5-7	7-2	11 4	1896	.....
ft.	252	16,020	M	5,406	AVS	2	5	1	21	..	...	1	18½	3×3 / 4	2	7-9	9-6	18.14	Nov. 24, 1898	.....
ft.	216	13,500	M	4,000	AVS	2	3½	1	20½	..	...	1	20	6 / 5	2	7-4	9-11½	33 9	1897	.....
	225	13,200	M	3,937	IVS	2	6	4	12	2	5×10 / 6	2	...	8 / 8	2	6-10	9-1½	16.4	Feb. 18, 1899	.....
.	118.75	5,552	M	2,366	AVS	2	4 28	1	13.19	..	...	2	18	4 / 3	2	7-6	10-9½	14.75	1897	.....
.	118.75	5,552	M	2,366	AVS	2	4.28	1	13.19	..	...	2	18	4 / 3	2	7 6	10-9½	14.75	Apr. 25, 1901	.....
.	118.75	5,552	M	2,366	AVS	2	4.28	1	13.19	..	...	2	18	4 / 3	2	7-6	10-9½	14.75	1898	.....
.	118.75	5,552	M	2,366	AVS	2	4.28	1	13.19	..	...	2	18	4 / 3	2	7-6	10-9½	14.75	1898	.....
.	150	7,575	M	2,482	...	..	...	..	...	..	...	2	18	4 / 3	2	5-6	8-11	11 52	Oct. 20, 1900	.....
.	150	7,575	M	2,482	...	..	...	..	...	..	...	2	18	4 / 3	2	5-6	8-11	11.52	1898	.....
	157.5	8,406	M	2,959	AVBD	2	4	1	14	..	...	2	19	6 / 5	2	6-5	9-4	12.9	July 2, 1901	.....
	157.5	8,406	M	2,959	AVBD	2	4	1	14	..	...	2	19	6 / 5	2	6-5	9-4	12 9	1898	.....
ft.	137	7,548	M	2,501	VABD	2	6	1	11	..	...	2	18	4 / 3	2	5-8	9	10.3	1898	.....
ft.	137	7,548	M	2,501	VABD	2	6	1	11	..	...	2	18	4 / 3	2	5-8	9	10.3	Apr. 2, 1901	.....
ft.	137	7,548	M	2,501	VABD	2	6	1	11	..	...	2	18	4 / 3	2	5-8	8-11½	10.2	1898	.....
ft.	137	7,548	M	2,480	VABD	2	6	1	11	..	...	2	18	4 / 3	2	6-3	9-4½	14.37	Nov. 28, 1900	.....
	137	7,800	M	2,481.5	VABD	2	6	1	11	..	...	2	18	5 / 3	2	...	...	...	1898	.....
e.	47	2,242	M	...	...	..	...	..	...	..	...	..	...	..	1	...	...	...	1898	.....
	...	...	..	...	...	..	...	..	...	..	...	..	...	..	1	...	...	...	1898	Purchased abr
	...	...	..	...	...	..	...	..	...	..	...	..	...	..	1	...	...	...	1898	Purchased abr
ft.	315	17,768	M	6,940	VABD	4	6	1	12	..	...	2	20	4½ / 5	2	7-3	10-10½	19.75	1898	.....
ft.	315	17,768	M	6,940	VABD	4	6	1	12	..	...	2	20	4½ / 5	2	7-3	10-10½	19.75	1898	.....
ft.	315	17,768	M	6,940	VABD	4	6	1	12	..	...	2	20	4½ / 5	2	7-3	10-10½	19 75	1898	.....
ft.	315	17,768	M	6,960	VABD	4	6	1	12	..	...	2	20	4½ / 5	2	7-10	10-3	21	1898	.....
ft.	315	17,768	M	6,960	VABD	4	6	1	12	..	...	2	20	4½ / 5	2	7-10	10-3	21	1898	.....
t.	294	17,612	M	5,992	VAS	2	5	1	21	..	...	2	18½	3×3 / 4	2	7-9	9-6	18.14	1898	.....
ft.	294	17,612	M	5,992	VAS	2	5	1	21	..	...	2	18½	3×3 / 4	2	7-9	9-6	18.14	1898	.....
.	304	18,117	M	6,992	VAS	1	6	3	12	2	4×4 / 4	2	20	4½ / 4	2	7-3	12	17.66	1898	.....
.	304	18,117	M	6,992	VAS	1	6	3	12	2	4×4 / 4	2	20	4½ / 4	2	7-3	12	17.66	1898	.....
ft.	315	17,783	M	6,940	VABD	4	6	1	12	..	...	2	22	6 / 5	2	7-5	10-10	16 4	1898	.....
ft.	315	17,783	M	6,940	VABD	4	6	1	12	..	...	2	22	6 / 5	2	7-5	10-6	20	1898	.....
ft.	315	17,783	M	6,940	VABD	4	6	1	12	..	...	2	22	6 / 5	2	7-5	10-10	16.4	1898	.....
	315	17,782	M	6,938	VABD	4	6	1	12	..	...	2	20	5 / 5	2	...	...	...	1898	.....
ft.	315	17,768	M	6,992	VABD	4	6	1	12½	..	...	2	20	3×3 / 4	2	8	11-3	22 7	1898	.....
ft.	315	17,768	M	6,992	VABD	4	6	1	12½	..	...	2	20	3×3 / 4	2	8	11-3	22.7	1898	.....
ft.	315	17,768	M	6,992	VABD	4	6	1	12½	..	...	2	20	3×3 / 4	2	8	11-3	22.7	1898	.....
	...	...	..	...	...	..	...	..	...	..	...	..	...	..	..	...	...	...	.....	.....

Name.	Displacement.	Length on load-water line.	Beam.	Mean draught.	Speed.	Cylinders. Type.	H.P.	I.P.	2dI.P.	L.P.	Stroke.	Revolutions.	I.H.P. main engines, air, circulating pumps.	Steam pressure.	Vacuum.	Air pressure.	Boilers. Type.	Total grate surface.	Total heating surface.	Condenser. Cooling surface. M=Main. A=Aux.	
Cushing	105	138–9	14–3	4–10½	...	VQ	11½	16	22½	(22½	15	...	1,600	250	...	...	2 Thornycroft.	76.6	4,750	M	1,052
	...	...	...	...	22.5		...	...	...	22½)	...	370	1,720	245	24	2.7	.....	...	...	M	...
Ericsson	120	149–7	15–6	4–10½	24	VQ	11½	16	21½	30	16	...	1,800	250	...	...	2 Thornycroft.	85	4,698	M	1,379
	...	...	...	...	22.36		...	...	...		...	361.5	1,557	...	...	...	.....	...	...	M	...
Foote	142	160	16–0½	5	...	VT	12	19½	...	(22)	16	412	2,000	250	...	...	2 Mosher.	95	5,260	M	1,602
	138.3	...	...	...	24.53		...	...	...	(22)	...	395.7	2,400	...	22	4.18	.....	...	...	M	...
Rodgers	142	160	16–0½	5–5	24.5	VT	12	19½	...	(22)	16	412	2,000	250	...	...	2 Mosher.	95	5,260	M	1,602
	...	...	...	...	22.3		...	...	...	(22)	...	366	...	232	23	...	.....	...	...	M	...
Winslow	142	160	16–0½	5	24.5	VT	12	19½	...	(22)	16	412	2,000	250	...	...	2 Mosher.	95	5,260	M	1,602
	138	...	...	5–3½	24.8		...	...	...	(22)	...	394.4	...	...	23	...	.....	...	...	M	...
Porter	165	175	17–8½	4–8	26	VT	16	22½	...	(25)	16	395	3,200	250	...	...	3 Mod. Normand.	160.6	8,288	M	2,326
	...	...	...	...	28.6		...	...	...	(25)	...	389.5	...	196	23¼	...	.....	...	...	M	...
Dupont	165	175	17–8½	4–8	26	VT	16	22½	...	(25)	16	395	3,200	250	...	...	3 Mod. Normand.	160.6	8,288	M	2,326
	...	...	...	...	...		...	...	...	(25)	...	...	...	...	...	...	.....	...	...	M	...
Rowan	182	170	17	5–11½	26	VT	14½	23	...	(25½	18	395	3,200	250	...	...	3 Mosher.	143.4	7,890	M	2,599
	184.25	...	...	...	27.07		...	...	...	25½)	...	368	...	232	27.7	2.9	.....	...	...	M	...
Dahlgren	146.5	147	16–4½	4–7½	30	VT	17.22	24.78	...	37.37	21	340	4,200	230	...	...	2 Normand.	118.75	5,552	M	2,366
	...	...	...	...	29.75		...	...	...		...	314.4	...	226	26.8	...	.....	...	...	M	...
T. A. M. Craven	146.5	147	16–4½	4–7½	30	VT	17.22	24.78	...	37.37	21	340	4,200	230	...	...	2 Normand.	118.75	5,552	M	2,366
	138.72	...	...	4–3½	...		...	...	...		...	322	...	224	23.5	5	.....	...	...	M	...
Farragut	279	213–6	20–7½	6	30	VT	20	29	...	(30	18	400	5,600	240	...	...	3 Thornycroft.	196	9,912	M	2,813
	236.3	...	...	6–5½	30.62		...	...	...	30)	...	427.6	...	222.5	25	4.25	.....	...	...	M	...
Davis	134	146	15–4	5–10	22.5	VT	11½	19	...	(22½	15	395	1,750	250	...	...	2 Thornycroft.	88	4,763	M	1,400
	126	...	...	5–3½	23.4		...	...	...	22½)	...	382	...	212	23	2	.....	...	...	M	...
Fox	154	146	15–4	5–10	22.5	VT	11½	19	...	(22½	15	395	1,750	250	...	...	2 Thornycroft.	88	4,763	M	1,400
	123	...	...	5–2	23.13		...	...	...	22½)	...	380.4	...	202.5	25	2	.....	...	...	M	...
Morris	104.75	138–3	15–6	4–3	23	VT	12½	18	...	25	13½	410	1,750	225	...	...	2 Normand.	80	4,004	M	1,195
	98	...	...	...	...		...	...	...	...	...	451.9	...	195.5	25	1.75	.....	...	...	M	...
Talbot	46.5	99–6	12–6	3–9½	20.25	VT	12½	18	...	25	13½	400	850	225	...	...	1 Normand.	38	1,870	M	600
	45.75	...	...	...	21.15		...	...	...	...	...	437.9	...	199.8	23.4	3.3	.....	...	...	M	...
Gwin	45.78	99–6	12–6	3–9½	20.25	VT	12½	18	...	25	13½	400	850	225	...	...	1 Normand.	38	1,870	M	600
	44.5	...	...	...	20.88		...	...	...	...	...	442.3	...	206	24.6	2.94	.....	...	...	M	...
Mackenzie	65	99–3	12–9½	4–3	20	VT	12	19½	...	(22	16	350	850	250	...	...	2 Thornycroft.	40	2,168	M	685
	...	...	...	...	...		...	...	...	22)	...	...	...	...	...	...	.....	...	...	M	...
McKee	65	99–3	12–9½	4–8½	20	VT	12	19½	...	(22	16	350	850	250	...	...	2 Thornycroft	40	2,294	M	677
	...	...	...	...	19 82		...	...	...	22)	...	307	...	215	25.5	3	.....	...	...	M	...
Stringham	340	225	22	6–6	30	VT	22	32½	...	(34	18	400	7,200	240	...	...	4 Thornycroft.	252	16,020	M	5,406
	...	...	...	...	...		...	...	...	34)	...	...	...	...	...	...	.....	...	...	M	...
Goldsborough	247.5	194–8	20–5	5	30	VT	19½	31½	...	(35½	20	360	5,850	250	...	...	3 Thornycroft.	216	13,500	M	4,000
	...	...	...	...	...		...	...	...	35½)	...	...	...	...	...	...	.....	...	...	M	...
Bailey	235	205	19–9½	6	30	VT	20	30½	...	(32	18	400	5,600	245	...	...	4 Seabury.	225	13,200	M	3,937
	...	...	...	...	...		...	...	...	32)	...	370	...	...	...	...	.....	...	...	M	...
Bagley	167	157	17	4–7½	28	VT	17.22	24.78	...	37.37	21	320	4,200	230	...	...	2 Normand.	118.75	5,552	M	2,366
	...	...	...	...	...		...	...	...	...	...	...	...	...	...	...	.....	...	...	M	...
Barney	167	157	17	4–7½	28	VT	17.22	24.78	...	37.37	21	320	4,200	230	...	...	2 Normand.	118.75	5,552	M	2,366
	...	...	...	...	26.16		...	...	...		...	290.8	...	200	20.3	6.04	.....	...	...	M	...
Biddle	167	157	17	4–7½	28	VT	17.22	24.78	...	37.37	21	320	4,200	230	...	...	2 Normand.	118.75	5,552	M	2,366
	...	...	...	...	28.6		...	...	...		...	307.3	...	219 5	22	4.8	.....	...	...	M	...
Blakely	166	175–1½	17–8½	4–8	26	VT	14	22	...	(25½	18	350	3,000	250	...	...	3 Normand.	150	7,575	M	2,482
	...	...	...	...	...		...	...	...	25½)	...	...	...	...	...	...	.....	...	...	M	...
DeLong	166	175–1½	17–8 7/10	4–8	26	VT	14	22	...	(25½	18	350	3,000	250	...	...	3 Normand.	150	7,575	M	2,482
	...	...	...	...	...		...	...	...	25½)	...	...	...	...	...	...	.....	...	...	M	...
Nicholson	174	174–6	17	4–6	26	VT	18	27	...	(27½	18	350	3,500	250	...	...	3 Mosher.	157.5	8,406	M	2,959
	...	...	...	...	...		...	...	...	27½)	...	...	...	...	...	...	.....	...	...	M	...
O'Brien	174	174–6	17	4–6	26	VT	18	27	...	(27½	18	350	3,500	250	...	...	3 Mosher.	157.5	8,406	M	2,959
	...	...	...	...	...		...	...	...	27½)	...	...	...	...	...	...	.....	...	...	M	...
Shubrick	165	175	17–6	4–8	26	VT	14	22	...	(25½	18	350	3,000	250	...	...	3 Thornycroft.	137	7,548	M	2,501
	185	...	...	...	26 2		...	...	...	25½)	...	365 8	...	256.5	23.5	2.83	.....	...	...	M	...
Stockton	165	175	17–6	4–8	26	VT	14	22½	...	(25½	18	350	3,000	250	...	...	3 Thornycroft.	137	7,548	M	2,501
	208	...	...	...	25.79		...	...	...	25½)	...	356½	3,975	230	22.2	3	.....	...	...	M	...
Thornton	165	175	17–6	4–8	26	VT	14	22	...	(25½	18	350	3,000	250	...	...	3 Thornycroft.	137	7,548	M	2,501
	...	...	...	...	...		...	...	...	25½)	...	...	...	...	...	...	.....	...	...	M	...
Tingey	165	175	17–6	4–8	26	VT	14	22	...	(25½	18	350	3,000	250	...	...	3 Thornycroft.	137	7,548	M	2,480
	...	...	...	...	...		...	...	...	25½)	...	...	...	...	...	...	.....	...	...	M	...
Wilkes	165	175	17–7½	4–8	26	VT	14	22	...	(25½	18	350	3,000	250	...	...	3 Seabury.	137	7,800	M	2,481.5
	...	...	...	...	...		...	...	...	25½)	...	...	...	...	...	...	.....	...	...	M	...
Somers	190	149–3½	17–6	5–10½	23	VQ	17	24	33 5/9	42½	18½	...	...	...	...	...	1 Locomotive.	47	2,242	M	...
	...	...	...	...	...		...	...	...	...	...	...	...	...	...	...	.....	...	...	M	...
Manly	30	60–8	9–5	2–10½	17	...	...	...	...	...	...	...	...	...	...	...	.....	...	...	M	...
	...	...	...	...	...		...	...	...	...	...	...	...	...	...	...	.....	...	...	M	...
Bainbridge	420	245	23–7½	6–6	28	VT	20½	32	...	(38	22	327	8,000	300	...	...	4 Thornycroft.	315	17,768	M	6,940
	...	...	...	...	...		...	...	...	38)	...	...	...	...	...	...	.....	...	...	M	...
Barry	420	245	23–7½	6–6	28	VT	20½	32	...	(38	22	327	8,000	300	...	...	4 Thornycroft.	315	17,768	M	6,940
	...	...	...	...	...		...	...	...	38)	...	...	...	...	...	...	.....	...	...	M	...
Chauncey	420	245	23–7½	6–6	28	VT	20½	32	...	(38	22	327	8,000	300	...	...	4 Thornycroft.	315	17,768	M	6,940
	...	...	...	...	...		...	...	...	38)	...	...	...	...	...	...	.....	...	...	M	...
Dale	420	245	23–7½	6–6	28	VT	20½	32	...	(38	22	327	8,000	300	...	...	4 Thornycroft.	315	17,768	M	6,960
	...	...	...	...	...		...	...	...	38)	...	...	...	...	...	...	.....	...	...	M	...
Decatur	420	245	23–7½	6–6	28	VT	20½	32	...	(38	22	327	8,000	300	...	...	4 Thornycroft.	315	17,768	M	6,960
	...	...	...	...	...		...	...	...	38)	...	...	...	...	...	...	.....	...	...	M	...
Hopkins	408	244	24–6	6	29	VT	22	32½	...	(34	18	400	7,200	240	...	...	4 Thornycroft.	294	17,612	M	5,992
	...	...	...	...	...		...	...	...	34)	...	...	...	...	...	...	.....	...	...	M	...
Hull	408	244	24–6	6	29	VT	22	32½	...	(34	18	400	7,200	240	...	...	4 Thornycroft.	294	17,612	M	5,992
	...	...	...	...	...		...	...	...	34)	...	...	...	...	...	...	.....	...	...	M	...
Lawrence	400	240–10	22–3	6–1½	28	VT	22	31	...	(34	20	360	8,400	250	...	...	4 Fore River.	304	18,117	M	6,992
	...	...	...	...	...		...	...	...	34)	...	...	...	...	...	...	.....	...	...	M	...
Macdonough	400	240–10	22–3	6–1½	28	VT	22	31	...	(34	20	360	8,400	250	...	...	4 Fore River.	304	18,117	M	6,992
	...	...	...	...	...		...	...	...	34)	...	...	...	...	...	...	.....	...	...	M	...
Paul Jones	420	245	23–7½	6–6	28	VT	20½	32	...	(38	22	327	8,000	300	...	...	4 Thornycroft.	315	17,783	M	6,940
	...	...	...	...	...		...	...	...	38)	...	...	...	...	...	...	.....	...	...	M	...
Perry	420	245	23–7½	6–6	28	VT	20½	32	...	(38	22	327	8,000	300	...	...	4 Thornycroft.	315	17,783	M	6,940
	...	...	...	...	...		...	...	...	38)	...	...	...	...	...	...	.....	...	...	M	...
Preble	420	245	23–7½	6–6	28	VT	20½	32	...	(38	22	327	8,000	300	...	...	4 Thornycroft.	315	17,783	M	6,940
	...	...	...	...	...		...	...	...	38)	...	...	...	...	...	...	.....	...	...	M	...
Stewart	420	245	23–7½	6–6	28	VT	20½	32	...	(38	22	327	8,000	300	...	...	4 Seabury.	315½	17,782	M	6,938
	...	...	...	...	...		...	...	...	38)	...	...	...	...	...	...	.....	...	...	M	...
Truxtun	433	248	23–3	6	28	VT	23	34	...	(37	22	327	8,300	240	...	...	4 Thornycroft.	315	17,768	M	6,992
	...	...	...	...	...		...	...	...	37)	...	...	...	...	...	...	.....	...	...	M	...
Whipple	433	248	23–3	6	28	VT	23	34	...	(37	22	327	8,300	240	...	...	4 Thornycroft.	315	17,768	M	6,992
	...	...	...	...	...		...	...	...	37)	...	...	...	...	...	...	.....	...	...	M	...
Worden	433	248	23–3	6	28	VT	23	34	...	(37	22	327	8,300	240	...	...	4 Thornycroft.	315	17,768	M	6,992
	...	...	...	...	...		...	...	...	37)	...	...	...	...	...	...	.....	...	...	M	...

surface.	Condenser.		Main air pump.							Main circulating pump.			Propeller.				Date.	Remarks.	Number.
	Cooling surface.		Type.	Number.	Stroke.	One pump.				Number.	Diameter of runner.	Dia. cyl. / Stroke.	Number.	Diameter.	Mean pitch.	Helicoidal area of one screw.			
						Water.		Steam.											
	M=Main. A=Aux.					No. cyls.	Dia.	No. cyls.	Dia.										
,750	M	1,052	IVS	1	5	3	10	2	$3\frac{1}{2}\times\frac{3\frac{1}{2}}{5}$	1	$13\frac{3}{4}$	$\frac{4}{4}$	2	4-3	8-4½	9.35	1889	.....	1
,698	M	1,379	HAS	2	3	1	14	..	...	1	$14\frac{3}{4}$	$\frac{5}{3\frac{1}{2}}$	2	4-9	7-8	8.5	Mar., 1890	.....	2
,260	M	1,602	HABD	2	5	2	5½	..	...	2	15	$\frac{4}{3}$	2	5-2	7-10	9.68	1894	.....	3
,260	M	1,602	HABD	2	5	2	5½	..	...	2	15	$\frac{4}{3}$	2	5-3	$7-9\frac{1}{2}$	9.67	June 25, 1897	.....	4
,260	M	1,602	HABD	2	5	2	5½	..	...	2	15	$\frac{4}{3}$	2	5-3	$7-9\frac{1}{2}$	9.67	Mar. 22, 1898	.....	5
,288	M	2,326	IVS	2	4	3	10	2	$4\times\frac{4}{5}$	2	$13\frac{3}{4}$	$\frac{4}{4}$	2	5-4	8-8½	10.75	Dec. 1, 1897	.....	6
,288	M	2,326	IVS	2	4	3	10	2	$4\times\frac{4}{5}$	2	$13\frac{3}{4}$	$\frac{4}{4}$	2	5-4	8-8½	10.3	Feb. 10, 1897	.....	7
,890	M	2,599	HABD	2	6	2	6½	..	...	2	19	$4\frac{1}{4}$	2	6	$9-5\frac{1}{2}$	13.26	1895	.....	8
,552	M	2,366	AVS	2	4.28	1	13.19	..	...	2	9	$\frac{1\frac{1}{2}}{2\frac{1}{2}}$	2	6-5	$11-5\frac{1}{2}$	13.63	Jan. 6, 1899	.....	9
,552	M	2,366	AVS	2	4.28	1	13.19	..	...	2	9	$\frac{1\frac{1}{2}}{2\frac{1}{2}}$	2	6-5	$11-6\frac{1}{2}$	13.63	Oct. 27, 1899	.....	10
,912	M	2,813	AVS	2	$3\frac{1}{2}$	1	20	..	...	1	26	$\frac{5}{4}$	2	6-9	8-9	12	1896	.....	11
,763	M	1,400	HABD	2	4½	2	5½	..	...	1	16	$\frac{5}{3\frac{1}{2}}$	2	$4-10\frac{1}{2}$	7-3	8.5	Feb. 21, 1900	.....	12
,763	M	1,400	HABD	2	4½	2	5½	..	...	1	16	$\frac{5}{3\frac{1}{2}}$	2	$4-10\frac{1}{2}$	7-3	8.5	1896	.....	13
,004	M	1,195	IVS	2	4	3	10	2	$4\times\frac{4}{5}$	1	14	$\frac{4}{4}$	2	4-8	$6-2\frac{1}{2}$	6.9	Dec. 2, 1898	.....	14
,870	M	600	IVS	1	4	3	10	2	$3\frac{1}{2}\times\frac{3\frac{1}{2}}{5}$	1	$11\frac{7}{8}$	$\frac{3\frac{1}{2}}{3\frac{1}{2}}$	1	4-8	6	6.9	Nov. 24, 1898	.....	15
,870	M	600	IVS	1	4	3	10	2	$3\frac{1}{2}\times\frac{3\frac{1}{2}}{5}$	1	$11\frac{7}{8}$	$\frac{3\frac{1}{2}}{3\frac{1}{2}}$	1	4-8	6-3	6.9	Feb. 18, 1899	.....	16
,168	M	685	HABD	1	5	2	5½	..	...	1	15	$\frac{4}{3}$	1	5-3	6-7	11	Apr. 17, 1898	.....	17
,294	M	677	HABD	1	5	2	5½	..	...	1	15	$\frac{4}{3}$	1	5-7	7-2	11 4	1896	.....	18
,020	M	5,406	AVS	2	5	1	21	..	...	1	$18\frac{3}{4}$	$\frac{3\times3}{4}$	2	7-9	9-6	18.14	May 2, 1898	.....	19
,500	M	4,000	AVS	2	$3\frac{1}{2}$	1	$20\frac{1}{2}$	..	...	1	20	$\frac{6}{5}$	2	7-4	$9-11\frac{7}{8}$	33 9	1897	.....	20
,200	M	3,937	IVS	2	6	4	12	2	$5\times\frac{10}{6}$	2	...	$\frac{5}{3\frac{1}{2}}$	2	6-10	$9-1\frac{1}{2}$	16.4	1897	.....	21
,552	M	2,366	AVS	2	4 28	1	13.19	..	...	2	18	$\frac{3\frac{1}{2}}{3\frac{1}{2}}$	2	7-6	$10-9\frac{1}{2}$	14.75	Apr. 25, 1901	.....	22
,552	M	2,366	AVS	2	4.28	1	13.19	..	...	2	18	$\frac{3\frac{1}{2}}{3\frac{1}{2}}$	2	7-6	$10-9\frac{1}{2}$	14.75	1898	.....	23
,552	M	2,366	AVS	2	4.28	1	13.19	..	...	2	18	$\frac{3\frac{1}{2}}{3\frac{1}{2}}$	2	7-6	$10-9\frac{1}{2}$	14.75	Oct. 20, 1900	.....	24
,575	M	2,482	...	..	...	..	...	..	...	2	18	$\frac{3\frac{1}{2}}{3\frac{1}{2}}$	2	5-6	8-11	11 52	1898	.....	25
,575	M	2,482	...	..	...	..	...	..	...	2	18	$\frac{3\frac{1}{2}}{3\frac{1}{2}}$	2	5-6	8-11	11.52	1898	.....	26
,406	M	2,959	AVBD	2	4	1	14	..	...	2	19	$\frac{6\frac{1}{2}}{6}$	2	6-5	9-4	12.9	1898	.....	27
,406	M	2,959	AVBD	2	4	1	14	..	...	2	19	$\frac{6\frac{1}{2}}{6}$	2	6-5	9-4	12 9	1898	.....	28
,548	M	2,501	VABD	2	6	1	11	..	...	2	18	$\frac{3\frac{1}{2}}{3\frac{1}{2}}$	2	5-8	9	10.3	1898	.....	29
,548	M	2,501	VABD	2	6	1	11	..	...	2	18	$\frac{3\frac{1}{2}}{3\frac{1}{2}}$	2	5-8	9	10.3	Apr. 2, 1901	.....	30
,548	M	2,501	VABD	2	6	1	11	..	...	2	18	$\frac{3\frac{1}{2}}{3\frac{1}{2}}$	2	5-8	$8-11\frac{1}{2}$	10.2	Nov. 28, 1900	.....	31
,548	M	2,480	VABD	2	6	1	11	..	...	2	18	$\frac{3\frac{1}{2}}{3\frac{1}{2}}$	2	6-3	$9-4\frac{1}{2}$	14.37	1898	.....	32
,800	M	2,481.5	VABD	2	6	1	11	..	...	2	18	$\frac{3\frac{1}{2}}{3\frac{1}{2}}$	2	...	...	...	1898	.....	33
,242	M	...	...	..	...	..	...	..	...	..	...	$\frac{5}{3}$	1	...	...	...	.....	Purchased abroad.	34
...	..	...	...	..	...	..	...	..	...	..	...	..	1	...	...	...	.....	Purchased abroad.	35
,768	M	6,940	VABD	4	6	1	12	..	...	2	20	$4\frac{1}{2}$	2	7-3	10-10½	19.75	1898	.....	36
,768	M	6,940	VABD	4	6	1	12	..	...	2	20	$4\frac{1}{2}$	2	7-3	10-10½	19.75	1898	.....	37
,768	M	6,940	VABD	4	6	1	12	..	...	2	20	$4\frac{1}{2}$	2	7-3	10-10½	19 75	1898	.....	38
,768	M	6,960	VABD	4	6	1	12	..	...	2	20	$4\frac{1}{2}$	2	7-10	10-3	21	1898	.....	39
,768	M	6,960	VABD	4	6	1	12	..	...	2	20	$4\frac{1}{2}$	2	7-10	10-3	21	1898	.....	40
,612	M	5,992	VAS	2	5	1	21	..	...	2	$18\frac{3}{4}$	$\frac{3\times3}{4}$	2	7-9	9-6	18.14	1898	.....	41
,612	M	5,992	VAS	2	5	1	21	..	...	2	$18\frac{3}{4}$	$\frac{3\times3}{4}$	2	7-9	9-6	18.14	1898	.....	42
,117	M	6,992	VAS	1	6	3	12	2	$4\times\frac{4}{4}$	2	20	$4\frac{1}{4}$	2	7-3	12	17.66	1898	.....	43
,117	M	6,992	VAS	1	6	3	12	2	$4\times\frac{4}{4}$	2	20	$4\frac{1}{4}$	2	7-3	12	17.66	1898	.....	44
,783	M	6,940	VABD	4	6	1	12	..	...	2	22	$\frac{6}{5}$	2	7-5	10-10	16 4	1898	.....	45
,783	M	6,940	VABD	4	6	1	12	..	...	2	22	$\frac{6}{5}$	2	7-5	10-6	20	1898	.....	46
,783	M	6,940	VABD	4	6	1	12	..	...	2	22	$\frac{6}{5}$	2	7-5	10-10	16.4	1898	.....	47
,782	M	6,938	VABD	4	6	1	12	..	...	2	20	$\frac{6}{5}$	2	...	...	...	1898	.....	48
,768	M	6,992	VABD	4	6	1	12½	..	...	2	20	$\frac{3\times3}{4}$	2	8	11-3	22 7	1898	.....	49
,768	M	6,992	VABD	4	6	1	12½	..	...	2	20	$\frac{3\times3}{4}$	2	8	11-3	22.7	1898	.....	50
,768	M	6,992	VABD	4	6	1	12½	..	...	2	20	$\frac{3\times3}{4}$	2	8	11-3	22.7	1898	.....	51

DESCRIPTION OF PISTON ROD AND CROSSHEAD

FIRST SYLLABLE PISTON ROD

PISTON END: T, D, P, C, H, G, B

SECTION: A, O

CROSSHEAD END: T, D, P, C, B, S, K, X, F, N

SECOND SYLLABLE

CROSSHEAD PIN AND BRASSES: FE, FI, SE, SI

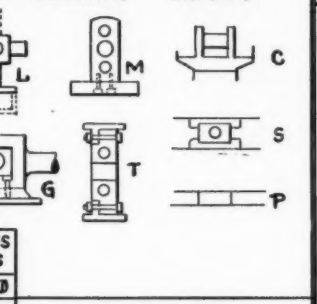
THIRD SYLLABLE–CROSSHEAD GUIDE

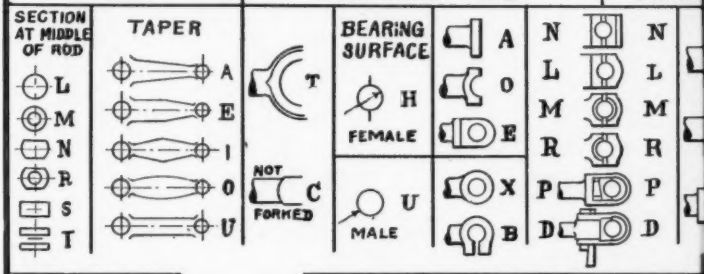
SECTION OF GUIDES: E, I, OI, A, U

MANNER OF SECURIN: N, L, R, G

	NAME OF SHIP	DIA. OF H.P. CYL.	Boiler Press-ure	DESCRIPTION OF PISTON ROD AND CROSSHEAD	DIAMETER OF ROD	LENGTH OF ROD	AREA OF SECTION OF ROD	SPECIFIED ULTIMATE STRENGTH OF METAL	PISTON ROD END FASTENINGS: PISTON DIMENSIONS OF FASTENINGS	CROSSHEAD DIMENSIONS OF	CROSSHEAD No OF	CROSSHEAD GUIDES AND SLIPPERS: FORWARD DIMENSIONS OF SLIPPER	BACKWARD DIMENSIONS OF SLIPPER	R
1	*Dale*	20½	250*	TON-SEL-ER	4½, 2⅜	39⅞	8.246	95,000	3½, 6th, ½	2½, 6th (?), ½	2	11 ×16	2 ×3 ×16	* 1
2	*Decatur*	20½	250*	TON-SEL-ER	4½, 2⅜	39⅞	8.246	95,000	3½, 6th, ½	2½, 6th (?), ½	2	11 ×16	2 ×3 ×16	* 1
3	*Shubrick*	14	250	TON-SEL-ER	3, 1⅜*	29⅞	4.489	95,000	2½, 6th, ⅜†	1⅞, 5th	2	7½×13½	2 ×2 ×13½	* 2 † 4
4	*Stockton*	14	250	TON-SEL-ER	3, 1⅜*	29⅞	4.489	95,000	2½, 6th, ⅜†	1⅞, 5th	2	7½×13½†	2 ×2 ×13½	† 3 § 5
5	*Thornton*	14	250	TON-SEL-ER	3, 1⅜*	29⅞	4.489	95,000	2½, 6th, ⅜†	1⅞, 5th	2	7½×13½†	2 ×2 ×13½	* 6
6	*Ericsson*	11½	250	TAN-SEL-EM	2½	25*	3.547	65,000	1⅞, 5th	1½, 6th, 1 1/16	2	7½× 9½	2 ×1½× 9½	
7	*Farragut*	20	240	TON-SER-EM	3⅜, 2½	31½	6.136	80,000	3⅜, 6th	2½, 1½	2	10 × 12	2 ×2 ×12	
8	*Dahlgren*	17.22	230	DAN-SER-IN	2.77	30.62	6.026	80,000	2.25, 4½th	1⅜, 5th	2	6.46×10.50	6.46×7.39	
9	*T. A. M. Craven*	17.22	230	DAN-SER-IN	2.77	30.62	6.026	80,000	2 25, 4½th	1⅜, 5th	2	6.46×10.50	6.46×7.39	
10	*Davis*	11⅝	250	DON-SEL-EM	2⅛, 1⅜*	26 3/16	3.424	80,000	2, 4½th, ½	1⅜, 5½th	2	8½× 9⅜†	2⅝×2½× 9⅜	* 7 † 9
11	*Fox*	11⅝	250	DON-SEL-EM	2⅛, 1⅜*	26 3/16	3.424	80,000	2, 4½th, ½	1⅜, 5½th	2	8½× 9⅜†	2⅝×2½× 9⅜	† 8 § 10
12	*Morris*	12½	225	CAX-SEN-OR	1⅜*	23⅜	2.761	70,000	1⅜, 11th	1⅜, 5th	1	7½× 8½	2 ×2 × 8½	*11
13	*Talbot*	12½	225	CAX-SEN-OR	1⅜*	23⅜	2.761	70,000	1⅜, 11th	1⅜, 5th	1	7½× 8½	2 ×2 × 8½	*11
14	*Gwin*	12½	225	CAX-SEN-OR	1⅜*	23⅜	2.761	70,000	1⅜, 11th	1⅜, 5th	1	7½× 8½	2 ×2 × 8½	*11
15	*Mackenzie*	12	250	DON-SEL-EM	2⅛, 1⅜*	26⅜	3.424	80,000	2, 6th	1⅛, 5½th	2	8½×10	2 ×2½×10	*12
16	*McKee*	12	250	DAN-SEL-EM	2⅛	26⅜	4.430	80,000	2, 6th	1⅛, 5½th	2	8½×10	2 ×2½×10	
17	*Foote*	12	250	TON-SEL-EM	2⅛, 1⅜*	26⅜	3.424	65,000	2, 6th, 5/16	1⅛, 5½th, 1 5/16	2	8½×10	2 ×2½×10	*13
18	*Rodgers*	12	250	TON-SEL-EM	2⅛, 1⅜*	26⅜	3.424	65,000	2, 6th, 5/16	1⅛, 5½th, 1 5/16	2	8½×10	2 ×2½×10	*13
19	*Winslow*	12	250	TON-SEL-EM	2⅛, 1⅜*	26⅜	3.424	65,000	2, 6th, 5/16	1⅛, 5½th, 1 5/16	2	8½×10	2 ×2½×10	*13 *14
20	*Dupont*	16	250	CAC-FIT-OIN	2⅜*	55½†	5.940	75,000	2⅜, 7th	2⅜, 7th	1	11 ×10	2 ×4½×10	*14 †15
21	*Porter*	16	250	CAC-FIT-OIN	2⅜*	55½†	5.940	75,000	2⅜, 7th	2⅜, 7th	1	11 ×10	2 ×4½×10	†15
22	*Rowan*	14½	250	PON-SEL-EM	3, 1⅜*	29½	4.995	75,000	2⅜, 6th	1½, 5th	2	10 ×12	2 ×2½×12	*16
23	*Basley*	20	245*	TON-SEM-ER	3⅜, 2½	32	6.136	95,000	3⅜, 5th, ⅜	2, 6th, ½ (?)	2	9 ×16	2 ×2½×16	
24	*Stringham*	22	240	TON-SEL-ER	4½, 2	32⅜	11.044	95,000	3½, 6th, 1	2½, 6th, ½	2	11 ×17	2 ×2½×17	
25	*Goldsborough*	19⅜	250	DON-SEM-ER	4, 2½*	30⅛	7.657	95,000	3⅜, 6th, 1	2, 6th, ½	2	12 ×14	2 ×2⅜×14	*17
26	*Nicholson*	18	250	TON-SEL-ER	3½, 2	30	6.479	95,000	2⅜, 8th, ⅜	2, 4½th	2	9 ×14	2 ×3½×14	
27	*O'Brien*	18	250	TON-SEL-ER	3½, 2	30	6.479	95,000	2⅜, 8th, ⅜	2, 4½th	2	9 ×14	2 ×3½×14	
28	*Blakely*	14	250	TON-SEL-ER	3, 1⅜*	28 5/16	4.489	95,500	2⅛, 4th (?), ⅜	1⅜, 5th	2	7½×13½†	2 ×2½×13½†	*18 †20
29	*DeLong*	14	250	TON-SEL-ER	3, 1⅜*	28 5/16	4 489	95,000	2⅛, 4th (?), ⅜	1⅜, 5th	2	7½×13½†	2 ×2½×13½†	†19
30	*Lawrence*	22	240*	DON-SEL-EG	4½, 1½†	36	11.781	95,000	3½, 4th (?), ½	2⅛, 4th, ½	2	10 ×15	2 ×2 5/16×15	*21 *21
31	*Macdonough*	22	240*	DON-SEL-EG	4½, 1½†	36	11.781	95,000	3½, 4th (?), ½	2⅛, 4th, ½	2	10 ×15	2 ×2 5/16×15	†22 †22
32	*Stewart*	20½	250*	TON-SER-EM	4½, 2½	40½	8.246	95,000	3½, 6th, ½	2½, 6th, ½	2	11 ×16	2 ×1 3/16×16	*23
33	*Wilkes*	14	250	TAN-SEL-ER	3*	28 5/16	7.069	95,000	2½, 4th†	1⅞, 5th	2	7½×13½†	2 ×2½×13½	*24 †19 †25 §20
34	*Bainbridge*	20½	250*	TON-SER-EM	4½, 2½	40½	8.246	95,000	3½, 6th, ½	2½, 6th, ½	2	11 ×16	2 ×1½×16	*23
35	*Barry*	20½	250*	TON-SER-EM	4½, 2½	40½	8.246	95,000	3½, 6th, ½	2½, 6th, ½	2	11 ×16	2 ×1½×16	*23
36	*Chauncey*	20½	250*	TON-SER-EM	4½, 2½	40½	8.246	95,000	3½, 6th, ½	2½, 6th, ½	2	11 ×16	2 ×1½×16	*23
37	*Tingey*	14	250	TON-SEL-ER	3, 1⅜*	28 5/16	4.489	95,000	2⅛, 6th, ⅜	1⅜, 5th	2	7½×13½†	2 ×2½×13½†	*19 †26 †20
38	*Truxtun*	23	230*	TON-SEM-EM	4½, 2½	36⅛	10.995	95,000	3⅜, 6th, ½	2⅛, 8th, ½	2	12½×18	2 ×2½×18	*27
39	*Whipple*	23	230*	TON-SEM-EM	4½, 2½	36⅛	10.995	95,000	3⅜, 6th, ½	2⅛, 8th, ½	2	12½×18	2 ×2½×18	*27
40	*Worden*	23	230*	TON-SEM-EM	4½, 2½	36⅛	10.995	95,000	3⅜, 6th, ½	2⅛, 8th, ½	2	12½×18	2 ×2½×18	*27
41	*Paul Jones*	20½	250*	DON-SER-EM	4½, 2½	40½	8.246	95,000	3⅜, 6th, ½	2½, 1½	2	11 ×16	2 ×2½×16	*23
42	*Perry*	20½	250*	DON-SER-EM	4½, 2½	40½	8.246	95,000	3⅜, 6th, ½	2½, 1½	2	11 ×16	2 ×2½×16	*23
43	*Preble*	20½	250*	DON-SER-EM	4½, 2½	40½	8.246	95,000	3⅜, 6th, ½	2½, 1½	2	11 ×16	2 ×2½×16	*23
44	*Bagley*	12.22	230	DAN-SER-IN	2.77	30.87	6.026	95,000	2½, 4½th	1⅜, 5th	2	6.46×10.50	6.46×7.39	
45	*Barney*	12.22	330	DAN-SER-IN	2.77	30.87	6.026	95,000	2½, 4½th	1⅜, 5th	2	6.46×10.50	6.46×7.39	
46	*Biddle*	12.22	230	DAN-SER-IN	2.77	30.87	6.026	95,000	2½, 4½th	1⅜, 5th	2	6.46×10.50	6.46×7.39	
47	*Hopkins*	2	240	TON-SEL-ER	4½, 2	32⅜	11.044	95,000	3½, 6th, 1	2½, 6th, ½	2	11 ×17	2 ×2½×17	
48	*Hull*	22	240	TON-SEL-ER	4½, 2	32⅜	11.044	95,000	3½, 6th, 1	2½, 6th, ½	2	11 ×17	2 ×2½×17	

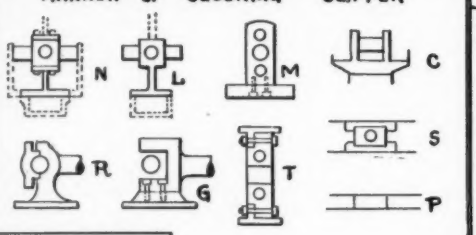
TABLE II.



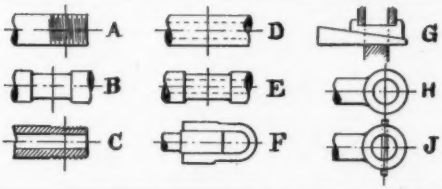


REMARKS	LENGTH OF ROD ℄ TO ℄ l	RAD. OF CRANK r	RATIO $\frac{l}{r}$	DESCRIPTION OF ROD	SMALLEST SECTION OF ROD: DIMENSIONS	SHAPE	AREA	SPECIFIED ULTIMATE STRENGTH OF METAL	SECTION AT MIDDLE: DIMENSIONS	SHAPE
* 1 1. The boiler pressure is 300 lbs. Reduced at boiler to 250 lbs.	46⅜	11	4.25	MA-TUX-MO	3⅞, 2½	M	7 817	95,000	4.2, 2½	M
* 1	46⅜	11	4.25	MA-TUX-MO	3⅞, 2½	M	7.817	95,000	4.2, 2½	M
* 2 ‡ 4 † 3 § 5 2. L.P. rod has 2″ hole.	40	9	4 44	SAI-TUX-LA*	4.05×1½	S	5.063	95,000	4.45×2	S
	40	9	4.44	SAI-TUX-LA*	4.05×1½	S	5.063	95,000	4 45×2	S
* 6 3. L.P. rod has 1″ hole through fastening.	40	9	4.44	SAI-TUX-LA*	4 05×1½	S	5.063	95,000	4.45×2	S
	38	8	4.75	MA-TUX-NA	2½, 1½	M	2.749	65,000	2.35, 1½	M
4. L.P. surface is 6⅛″×11⅛″.	40	9	4 44	MA-TUX-RO	3⅜, 2	M	6.480	80,000	3.73, 2	M
5. L.P. backing surface is 2× 1⅜″×11⅛″	46.19	10½	4.4	ME-TUX-RO*	2.86, 1.68	M	4.208	80,000	3.02, 1.68	M
	46 19	10½	4.4	ME-TUX-RO*	2.86, 1.68	M	4.208	80,000	3.02, 1.68	M
* 7 ‡ 9 † 8 § 10 6. I.P. and L.P. rods are 23⅞″ long.	37⅛	7½	5	MA-TUX-NA	2½, 1½*	M	2.749	80,000	2.37, 1½*	M
	37⅛	7½	5	MA-TUX-NA	2½, 1½*	M	2.749	80,000	2.37, 1½*	M
* 11 7. L.P. rods have holes 1¼″ dia.	33½	6¾	4.93	TE-TUX-LA	two 2½×⅜	T	2.656	70,000	two 2½×⅜	T
* 11	33½	6¾	4.93	TE-TUX-LA	two 2½×⅜	T	2 656	70,000	two 2½×⅜	T
* 11	33½	6¾	4.93	TE-TUX-LA	two 2½×⅜	T	2.656	70,000	two 2½×⅜	T
* 12 8. I.P. rods are 26 5/16″ long.	40	8	5	MA-TUX-NA	2⅜, 1⅜*	M	2.945	80,000	2.47, 1⅜*	M
9. L.P. surface, 5⅛″×9⅜″.	36	8	4.5	MA-TUX-NA	2⅜, 1⅜*	M	2 945	80,000	2.47, 1⅜*	M
* 13	40	8	5	MA-TUX-NA	2⅜, 1⅜*	M	2.945	65,000	2.47, 1⅜*	M
* 13 10. L.P. backing surface is 2× 1 5/16″×9⅜″.	40	8	5	MA-TUX-NA	2⅜, 1⅜*	M	2.945	65,000	2.47, 1⅜*	M
* 13 * 14 † 15	40	8	5	MA-TUX-NA	2⅜ 1⅜*	M	2.945	65,000	2.47, 1⅜*	M
11. L.P. rod has hole 1½″ diam.	36	8	4.5	SA-THAL-LA	3⅜×1½	S	6.344	75,000	3.94×1½	S
† 15	36	8	4.5	SA-THAL-LA	3⅜×1½	S	6.344	75,000	3.94×1½	S
* 16 12. L.P. rod has hole 1⅜″ diam.	45	9	5	MA-TUX-MO	2⅞, 1⅜*	M	4-4179	75,000	3.03, 1⅜*	M
13. Holes in L.P. rods are 1⅜″ diam.	40	9	4.44	RA-TUX-MO	3½, 2½	M	5.645	95,000	4.16, 3½, 2½	R
	40	9	4.44	MA-TUX-MO	4 , 2*	M	9.424	95,000	4.26, 2*	M
* 17 14. 2d L.P. rod has hole 1¼″ dia.	44	10	4.4	MA-TUX-RO	3⅜, 2	M	7.179	95,000	3 84, 2	M
15. I.P. and 1st L.P. rods are 29⅛″ long.	36	9	4	TA-TUX-LA	two 3½×1	T	7.500	95,000	two 4.45×1	T
	40	9	4	TA-TUX-LA	two 3½×1	T	7.500	95,000	two 4.45×1	T
* 18 ‡ 20 † 19 16. L.P. rods have holes 1⅜″ dia	40	9	4.44	SAI-TUX-LA*	4.05×1⅜	S	5.063	95,000	4.45×2	S
	40	9	4.44	SAI-TUX-LA*	4.05×1⅜	S	5.063	95,000	4.45×2	S
* 21 * 21 17. L.P. rod has 2⅜″ hole.	50	10	5	MA-TUX-LA	4½, 2½	M	10.21	95,000	4.46, 2½	M
† 22 ‡ 22 18. L.P. rod has 2″ hole.	50	10	5	MA-TUX-LA	4½, 2½	M	10.21	95,000	4.46, 2½	M
* 23	46⅜	11	4.25	MA-TUX-RO	3⅞, 2½	M	7.817	95,000	4.2, 2½	M
* 24 ‡ 19 † 25 § 20 19. L.P. surface is 6⅛″×11⅛″.	40	9	4.44	SAI-TUX-LA*	4.05×1⅜	S	5.063	95,000	4.45×2	S
20. L.P. backing surface is 2× 2½″×11⅛″.	46⅜	11	4.25	MA-TUX-MO	3⅞, 2½	M	7.817	95,000	4.18, 2½	M
* 23	46⅜	11	4.25	MA-TUX-MO	3⅞, 2½	M	7.817	95,000	4.18, 2½	M
* 23 21. Boiler pressure is 250 lbs.	46⅜	11	4.25	MA-TUX-MO	3⅞, 2½	M	7.817	95,000	4.18, 2½	M
* 19 ‡ 26 † 20 22. I.P. rod has 2½″ hole and L.P. rod has 2⅜″ hole.	40	9	4.44	SAI-TUX-LA*	3⅜×1½	S	4 688	95,000	4.28×2	S
* 27	46	10	4.6	MA-TUX-RO	4½, 2½	M	10.210	95,000	4 57, 2½	M
* 27 23 The boiler pressure is 300 lbs. Reduced at boiler to 250 lbs.	46	10	4.0	MA-TUX-RO	4½, 2½	M	10.210	95,000	4.57, 2½	M
* 27	46	10	4.6	MA-TUX-RO	4½, 2½	M	10.210	95,000	4.57, 2½	M
* 23 24. I.P. rod has 1⅜″ hole and	46⅜	11	4.25	MA-TUX-RO	3½, 2½	M	7.817	95,000	4.2, 2½	M
* 23 L.P. rod has 2″ hole.	46⅜	11	4.25	MA-TUX-RO	3½, 2½	M	7.817	95,000	4 2, 2½	M
* 23	46⅜	11	4.25	MA-TUX-RO	3½, 2½	M	7.817	95,000	4.2, 2½	M
25. I.P. and L.P. rods have ¼″ holes through fastening.	46 19	10½	4.4	ME-TUX-RO*	2.86, 1.68	M	4.207	95,000	3.02, 1.68	M
	46.19	10½	4.4	ME-TUX-RO*	2.86, 1.68	M	4.207	95,000	3.02, 1 68	M
26. L.P. backing surface is 2× 1⅜″×11⅛″.	46.19	10½	4 4	ME-TUX-RO*	2.86, 1.68	M	4.207	95,000	3.02, 1.68	M
	40	9	4.44	MA-TUX-MO	4, 2*	M	9.424	95,000	4.28, 2*	M
27. Boiler pressure, 240 lbs.	40	9	4.44	MA-TUX-MO	4, 2*	M	9.424	95,000	4.28, 2*	M

TABLE II.



AND CROSSHEAD						DESCRIPTION OF CONNECTING R										
D SYLLABLE—CROSSHEAD GUIDE AND SLIPPER						FIRST SYLLABLE BODY			SECOND SYLLABLE CROSSHEAD END							
OF GUIDES	MANNER OF SECURING SLIPPER					SECTION AT MIDDLE OF ROD	TAPER		BEARING SURFACE							
						L M N R S T	A E I O U		T	H FEMALE	A O E	N L M R				
									NOT FORKED C	U MALE	X B	P D				
STENING3	CROSSHEAD GUIDES AND SLIPPERS															
SSHEAD	FORWARD	BACKWARD				LENGTH OF ROD ℄ TO ℄ l	RAD. OF CRANK r	RATIO $\frac{l}{r}$	DESCRIPTION OF ROD	SMALLEST SECTION OF ROD			SPECIFIED ULTIMATE STRENGTH OF METAL	SECTI		
NSIONS OF	DIMENSIONS OF SLIPPER	DIMENSIONS OF SLIPPER		REMARKS						DIMENSIONS	SHAPE	AREA		DIME		
h (?), $\frac{5}{8}$	2	11 × 16	2 × 3 × 16	* 1	1. The boiler pressure is 300 lbs. Reduced at boiler to 250 lbs.	46$\frac{3}{8}$	11	4.25	MA-TUX-MO	3$\frac{7}{8}$, 2$\frac{1}{2}$	M	7 817	95,000	4.		
h (?), $\frac{5}{8}$	2	11 × 16	2 × 3 × 16	* 1		46$\frac{3}{8}$	11	4.25	MA-TUX-MO	3$\frac{7}{8}$, 2$\frac{1}{2}$	M	7.817	95,000	4.		
h	2	7$\frac{1}{8}$ × 13$\frac{1}{2}$	2 × 2 × 13$\frac{1}{2}$	* 2 † 4	2. L.P. rod has 2" hole.	40	9	4 44	SAI-TUX-LA*	4.05 × 1$\frac{1}{2}$	S	5.063	95,000	4.		
h	2	7$\frac{1}{8}$ × 13$\frac{1}{2}$	2 × 2 × 13$\frac{1}{2}$	† 3 § 5	3. L.P. rod has 1" hole through fastening.	40	9	4.44	SAI-TUX-LA*	4.05 × 1$\frac{1}{2}$	S	5.063	95,000	4		
h	2	7$\frac{1}{8}$ × 13$\frac{1}{2}$	2 × 2 × 13$\frac{1}{2}$			40	9	4.44	SAI-TUX-LA*	4 05 × 1$\frac{1}{2}$	S	5.063	95,000	4.		
h, $\frac{5}{16}$	2	7$\frac{1}{8}$ × 9$\frac{1}{2}$	2 × 1$\frac{1}{2}$ × 9$\frac{1}{2}$	* 6	4. L.P. surface is 6$\frac{1}{2}$" × 11$\frac{1}{2}$".	38	8	4.75	MA-TUX-NA	2$\frac{1}{2}$, 1$\frac{1}{2}$	M	2.749	65,000	2.		
	2	10 × 12	2 × 2 × 12			40	9	4 44	MA-TUX-RO	3$\frac{1}{2}$, 2	M	6.480	80,000	3.		
h	2	6.46 × 10.50	6.46 × 7.39		5. L.P. backing surface is 2 × 1$\frac{1}{2}$" × 11$\frac{1}{2}$"	46.19	10$\frac{1}{2}$	4.4	ME-TUX-RO*	2.86, 1.68	M	4.208	80,000	3.		
h	2	6.46 × 10.50	6.46 × 7.39			46.19	10$\frac{1}{2}$	4.4	ME-TUX-RO*	2.86, 1.68	M	4.208	80,000	3.		
th	2	8$\frac{1}{2}$ × 9$\frac{1}{2}$	2$\frac{1}{2}$ × 2$\frac{1}{2}$ × 9$\frac{1}{2}$	* 7 † 9	6. I.P. and L.P. rods are 23$\frac{3}{8}$" long.	37$\frac{1}{2}$	7$\frac{1}{2}$	5	MA-TUX-NA	2$\frac{1}{2}$, 1$\frac{1}{2}$*	M	2.749	80,000	2.		
th	2	8$\frac{1}{2}$ × 9$\frac{1}{2}$	2$\frac{1}{2}$ × 2$\frac{1}{2}$ × 9$\frac{1}{2}$	† 8 § 10		37$\frac{1}{2}$	7$\frac{1}{2}$	5	MA-TUX-NA	2$\frac{1}{2}$, 1$\frac{1}{2}$*	M	2.749	80,000	2.		
h	1	7$\frac{1}{2}$ × 8$\frac{1}{2}$	2 × 2 × 8$\frac{1}{2}$	*11	7. L.P. rods have holes 1$\frac{1}{4}$" dia.	33$\frac{1}{2}$	6$\frac{1}{2}$	4.93	TE-TUX-LA	two 2$\frac{1}{2}$ × $\frac{5}{8}$	T	2.656	70,000	two		
h	1	7$\frac{1}{2}$ × 8$\frac{1}{2}$	2 × 2 × 8$\frac{1}{2}$	*11		33$\frac{1}{2}$	6$\frac{1}{2}$	4.93	TE-TUX-LA	two 2$\frac{1}{2}$ × $\frac{5}{8}$	T	2 656	70,000	two		
h	1	7$\frac{1}{2}$ × 8$\frac{1}{2}$	2 × 2 × 8$\frac{1}{2}$	*11	8. L.P. rods are 26$\frac{5}{16}$" long.	33$\frac{1}{2}$	6$\frac{1}{2}$	4.93	TE-TUX-LA	two 2$\frac{1}{2}$ × $\frac{5}{8}$	T	2.656	70,000	two		
th	2	8$\frac{1}{2}$ × 10	2 × 2$\frac{1}{2}$ × 10	*12		40	8	5	MA-TUX-NA	2$\frac{1}{2}$, 1$\frac{1}{8}$*	M	2.945	80,000	2.		
h	2	8$\frac{1}{2}$ × 10	2 × 2$\frac{1}{2}$ × 10		9. L.P. surface, 5$\frac{1}{4}$" × 9$\frac{3}{4}$".	36	8	4.5	MA-TUX-NA	2$\frac{1}{2}$, 1$\frac{1}{8}$*	M	2.945	80,000	2.		
th, $\frac{5}{16}$	2	8$\frac{1}{2}$ × 10	2 × 2$\frac{1}{2}$ × 10	*13	10. L.P. backing surface is 2 × 1$\frac{5}{16}$" × 9$\frac{3}{4}$".	40	8	5	MA-TUX-NA	2$\frac{1}{2}$, 1$\frac{1}{8}$*	M	2.945	65,000	2.		
th, $\frac{5}{16}$	2	8$\frac{1}{2}$ × 10	2 × 2$\frac{1}{2}$ × 10	*13		40	8	5	MA-TUX-NA	2$\frac{1}{2}$, 1$\frac{1}{8}$*	M	2.945	65,000	2.		
th, $\frac{5}{16}$	2	8$\frac{1}{2}$ × 10	2 × 2$\frac{1}{2}$ × 10	*13 *14		40	8	5	MA-TUX-NA	2$\frac{1}{2}$ 1$\frac{1}{8}$*	M	2.945	65,000	2.		
h	1	11 × 10	2 × 4$\frac{1}{2}$ × 10	*14 †15	11. L.P. rod has hole 1$\frac{1}{2}$" diam.	36	8	4.5	SA-THAL-LA	3$\frac{1}{2}$ × 1$\frac{1}{2}$	S	6.344	75,000	3.		
h	1	11 × 10	2 × 4$\frac{1}{2}$ × 10	†15	12. L.P. rod has hole 1$\frac{1}{2}$" diam.	36	8	4.5	SA-THAL-LA	3$\frac{1}{2}$ × 1$\frac{1}{2}$	S	6.344	75,000	3.		
h	2	10 × 12	2 × 2$\frac{1}{2}$ × 12	*16		45	9	5	MA-TUX-MO	2$\frac{1}{2}$, 1$\frac{1}{8}$*	M	4.4179	75,000	3.		
h, $\frac{5}{16}$ (?)	2	9 × 16	2 × 2$\frac{1}{2}$ × 16		13. Holes in L.P. rods are 1$\frac{1}{8}$" diam.	40	9	4.44	RA-TUX-MO	3$\frac{1}{4}$, 2$\frac{1}{2}$	M	5.645	95,000	4.16,		
h, $\frac{5}{16}$	2	11 × 17	2 × 2$\frac{1}{2}$ × 17			40	9	4.44	MA-TUX-MO	4 , 2*	M	9.424	95,000	4.		
h, $\frac{5}{16}$	2	12 × 14	2 × 2$\frac{1}{2}$ × 14	*17	14. 2d L.P. rod has hole 1$\frac{1}{2}$" dia.	44	10	4.4	MA-TUX-RO	3$\frac{1}{2}$, 2	M	7.179	95,000	3		
h	2	9 × 14	2 × 3$\frac{1}{2}$ × 14		15. I.P. and 1st L.P. rods are 29$\frac{1}{2}$" long.	36	9	4	TA-TUX-LA	two 3$\frac{1}{2}$ × 1	T	7.500	95,000	two 4		
h	2	9 × 14	2 × 3$\frac{1}{2}$ × 14			36	9	4	TA-TUX-LA	two 3$\frac{1}{2}$ × 1	T	7.500	95,000	two 4		
h	2	7$\frac{1}{8}$ × 13$\frac{1}{2}$ †	2 × 2$\frac{1}{2}$ × 13$\frac{1}{2}$ †	*18 †20	16. L.P. rods have holes 1$\frac{1}{2}$" dia	40	9	4.44	SAI-TUX-LA*	4.05 × 1$\frac{1}{2}$	S	5.063	95,000	4.		
h	2	7$\frac{1}{8}$ × 13$\frac{1}{2}$ †	2 × 2$\frac{1}{2}$ × 13$\frac{1}{2}$ †	†19		40	9	4.44	SAI-TUX-LA*	4.05 × 1$\frac{1}{2}$	S	5.063	95,000	4.		
h, $\frac{5}{16}$	2	10 × 15	2 × 2$\frac{1}{2}$ × 15	*21 *21	17. L.P. rod has 2$\frac{1}{2}$" hole.	50	10	5	MA-TUX-LA	4$\frac{1}{2}$, 2$\frac{1}{2}$	M	10.21	95,000	4.		
h, $\frac{5}{16}$	2	10 × 15	2 × 2$\frac{1}{2}$ × 15	†22 †22	18. L.P. rod has 2" hole.	50	10	5	MA-TUX-LA	4$\frac{1}{2}$, 2$\frac{1}{2}$	M	10.21	95,000	4.		
h, $\frac{5}{16}$	2	11 × 16	2 × 1$\frac{1}{2}$ × 16	*23		46$\frac{1}{2}$	11	4.25	MA-TUX-RO	3$\frac{1}{2}$, 2$\frac{1}{2}$	M	7.817	95,000	4.		
h	2	7$\frac{1}{8}$ × 13$\frac{1}{2}$ †	2 × 2$\frac{1}{2}$ × 13$\frac{1}{2}$ †	*24 †19 †25 ‡20	19. L.P. surface is 6$\frac{1}{2}$" × 11$\frac{1}{2}$".	40	9	4.44	SAI-TUX-LA*	4.05 × 1$\frac{1}{2}$	S	5.063	95,000	4.		
h, $\frac{5}{16}$	2	11 × 16	2 × 1$\frac{1}{2}$ × 16	*23	20. L.P. backing surface is 2 × 2$\frac{1}{2}$" × 11$\frac{1}{2}$".	46$\frac{1}{2}$	11	4.25	MA-TUX-MO	3$\frac{7}{8}$, 2$\frac{1}{2}$	M	7.817	95,000	4.		
h, $\frac{5}{16}$	2	11 × 16	2 × 1$\frac{1}{2}$ × 16	*23		46$\frac{1}{2}$	11	4.25	MA-TUX-MO	3$\frac{7}{8}$, 2$\frac{1}{2}$	M	7.817	95,000	4.		
h, $\frac{5}{16}$	2	11 × 16	2 × 1$\frac{1}{2}$ × 16	*23	21. Boiler pressure is 250 lbs.	46$\frac{1}{2}$	11	4.25	MA-TUX-MO	3$\frac{7}{8}$, 2$\frac{1}{2}$	M	7.817	95,000	4.		
h	2	7$\frac{1}{8}$ × 13$\frac{1}{2}$ †	2 × 2$\frac{1}{2}$ × 13$\frac{1}{2}$ †	*19 †26 †20	22. I.P. rod has 2$\frac{1}{2}$" hole and L.P. rod has 2$\frac{1}{2}$" hole.	40	9	4.44	SAI-TUX-LA*	3$\frac{1}{2}$ × 1$\frac{1}{2}$	S	4 688	95,000	4.		
h, $\frac{5}{16}$	2	12$\frac{1}{2}$ × 18	2 × 2$\frac{1}{2}$ × 18	*27	23 The boiler pressure is 300 lbs. Reduced at boiler to 250 lbs.	46	10	4.6	MA-TUX-RO	4$\frac{1}{2}$, 2$\frac{1}{2}$	M	10.210	95,000	4		
h, $\frac{5}{16}$	2	12$\frac{1}{2}$ × 18	2 × 2$\frac{1}{2}$ × 18	*27		46	10	4.0	MA-TUX-RO	4$\frac{1}{2}$, 2$\frac{1}{2}$	M	10.210	95,000	4.		
h, $\frac{5}{16}$	2	12$\frac{1}{2}$ × 18	2 × 2$\frac{1}{2}$ × 18	*27		46	10	4.6	MA-TUX-RO	4$\frac{1}{2}$, 2$\frac{1}{2}$	M	10.210	95,000	4.		
	2	11 × 16	2 × 2$\frac{1}{2}$ × 16	*23	24. I.P. rod has 1$\frac{1}{8}$" hole and L.P. rod has 2" hole.	46$\frac{1}{2}$	11	4.25	MA-TUX-RO	3$\frac{7}{8}$, 2$\frac{1}{2}$	M	7.817	95,000	4.		
	2	11 × 16	2 × 2$\frac{1}{2}$ × 16	*23		46$\frac{1}{2}$	11	4.25	MA-TUX-RO	3$\frac{7}{8}$, 2$\frac{1}{2}$	M	7.817	95,000	4.		
	2	11 × 16	2 × 2$\frac{1}{2}$ × 16	*23	25. I.P. and L.P. rods have $\frac{1}{4}$" holes through fastening.	46$\frac{1}{2}$	11	4.25	MA-TUX-RO	3$\frac{7}{8}$, 2$\frac{1}{2}$	M	7.817	95,000	4.		
h	2	6.46 × 10 50	6.46 × 7.39			46 19	10$\frac{1}{2}$	4.4	MF-TUX-RO*	2.86, 1.68	M	4.207	95,000	3.		
h	2	6.46 × 10.50	6.46 × 7.39		26. L.P. backing surface is 2 × 1$\frac{3}{8}$" × 11$\frac{1}{2}$".	46.19	10$\frac{1}{2}$	4.4	ME-TUX-RO*	2.86, 1.68	M	4.207	95,000	3.		
h	2	6.46 × 10.50	6.46 × 7.39			46.19	10$\frac{1}{2}$	4 4	ME-TUX-RO*	2.86, 1.68	M	4.207	95,000	3.		
h, $\frac{5}{16}$	2	11 × 17	2 × 2$\frac{1}{2}$ × 17		27. Boiler pressure, 240 lbs.	40	9	4.44	MA-TUX-MO	4, 2*	M	9.424	95,000	4.		
h, $\frac{5}{16}$	2	11 × 17	2 × 2$\frac{1}{2}$ × 17			40	9	4.44	MA-TUX-MO	4, 2*	M	9.424	95,000	4.		

TING ROD					END FASTENINGS						
BLE ND	THIRD SYLLABLE CRANK END				DESCRIPTION OF WEAKEST POINT						
A	N	N	A								
O	L	L									
E	M	M	O								
	R	R									
X	P	P									
B	D	D	E								

SPECIFIED ULTIMATE STRENGTH OF METAL	SECTION AT MIDDLE OF ROD			CRANK END			CROSSHEAD END			PREPARED BY BUREAU OF STEAM ENGINEERING	
	DIMENSIONS	SHAPE	AREA	WEAKEST POINT	DIMENSIONS OF FASTENING	NUMBER OF FASTENINGS	WEAKEST POINT	DIMENSIONS OF FASTENINGS	NUMBER OF FASTENINGS	REMARKS	
95,000	4.2, $2\frac{1}{2}$	M	9.878	C	$2\frac{1}{2}$, 4th, $\frac{5}{8}$	2	H	$2\frac{1}{2}\times2\frac{1}{16}$	4		1
95,000	4.2, $2\frac{1}{2}$	M	9.878	C	$2\frac{1}{2}$, 4th, $\frac{5}{8}$	2	H	$2\frac{1}{2}\times2\frac{1}{16}$	4	1. The (A) taper is in the plane of motion, and the (I) taper is in the plane at right angles to the plane of motion.	2
95,000	4.45×2	S	8.90	A	$1\frac{7}{8}$, 5th	2	H	$1\frac{7}{8}\times1\frac{7}{16}$	4	*1	3
95,000	4.45×2	S	8.90	A	$1\frac{7}{8}$, 5th	2	H	$1\frac{7}{8}\times1\frac{7}{16}$	4	*1	4
95,000	4.45×2	S	8.90	A	$1\frac{7}{8}$, 5th	2	H	$1\frac{7}{8}\times1\frac{7}{16}$	4	*1	5
65,000	2.35, $1\frac{1}{4}$	M	3.11	A	$1\frac{1}{8}$, 6th	2	H	$1\frac{1}{16}\times1\frac{1}{32}$	4		6
80,000	3.73, 2	M	7.79	A	$2\frac{1}{2}$, $1\frac{1}{2}$	2	H	$1\frac{1}{2}\times1\frac{1}{2}$	4	2. The low-pressure rod has a $1\frac{1}{2}$-inch hole.	7
80,000	3.02, 1.68	M	4.94	A	$1\frac{3}{4}$, 5th	2	H	1.55×1.41	4	*4	8
80,000	3.02, 1.68	M	4.94	A	$1\frac{3}{4}$, 5th	2	H	1.55×1.41	4	*4	9
80,000	2.37, $1\frac{1}{4}$*	M	3.18	A	$1\frac{1}{8}$, $4\frac{1}{2}$th	2	H	$1\frac{1}{16}\times1\frac{1}{16}$	4	*5	10
80,000	2.37, $1\frac{1}{4}$*	M	3.18	A	$1\frac{1}{8}$, $5\frac{1}{2}$th	2	H	$1\frac{1}{16}\times1\frac{1}{16}$	4	*5	11
70,000	two $2\frac{1}{2}\times\frac{1}{2}$	T	3.59	A	1, 8th	4	H	$1\frac{1}{4}\times1\frac{1}{16}$	4	3. The low-pressure rod has a $1\frac{1}{2}$-inch hole.	12
70,000	two $2\frac{1}{2}\times\frac{1}{2}$	T	3.59	A	1, 8th	4	H	$1\frac{1}{4}\times1\frac{1}{16}$	4		13
70,000	two $2\frac{1}{2}\times\frac{1}{2}$	T	3.59	A	1, 8th	4	H	$1\frac{1}{4}\times1\frac{1}{16}$	4		14
80,000	2.47, $1\frac{1}{2}$*	M	3.31	A	$1\frac{1}{8}$, $5\frac{1}{2}$th	2	H	$1\frac{1}{4}\times1\frac{1}{4}$	4	*2	15
80,000	2.47, $1\frac{1}{2}$*	M	3.31	A	$1\frac{1}{8}$, $5\frac{1}{2}$th	2	H	$1\frac{1}{4}\times1\frac{1}{4}$	4	*2	16
65,000	2.47, $1\frac{1}{2}$*	M	3.31	A	$1\frac{1}{8}$, $5\frac{1}{2}$th	2	H	$1\frac{1}{4}\times1\frac{1}{4}$	4	*2	17
65,000	2.47, $1\frac{1}{2}$*	M	3.31	A	$1\frac{1}{8}$, $5\frac{1}{2}$th	2	H	$1\frac{1}{4}\times1\frac{1}{4}$	4	*2	18
65,000	2.47, $1\frac{1}{2}$*	M	3.31	A	$1\frac{1}{8}$, $5\frac{1}{2}$th	2	H	$1\frac{1}{4}\times1\frac{1}{4}$	4	*2	19
75,000	$3.94\times1\frac{1}{2}$	S	6.9	A	$1\frac{1}{2}$, 5th	2	A	$1\frac{1}{8}$, 6th	4		20
75,000	$3.94\times1\frac{1}{2}$	S	6.9	A	$1\frac{1}{2}$, 5th	2	A	$1\frac{1}{8}$, 6th	4		21
75,000	3.03, $1\frac{1}{2}$*	M	5.14	A	2, $4\frac{1}{2}$th	2	H	$1\frac{1}{2}\times1\frac{1}{2}$	4	*3	22
95,000	4.16, $3\frac{1}{4}$, $2\frac{1}{2}$	R	8.626	C	2, $4\frac{1}{2}$th, $\frac{5}{8}$	2	H	$1\frac{1}{2}\times1\frac{7}{16}$	4		23
95,000	4.26, 2*	M	11.11	C	$2\frac{1}{2}$, $4\frac{1}{2}$th, $\frac{5}{8}$	2	H	$2\times2\frac{1}{16}$	4	*6	24
95,000	3 84, 2	M	8.44	C	$2\frac{1}{2}$, $4\frac{1}{2}$th, $\frac{5}{8}$	2	H	$1\frac{13}{16}\times2\frac{1}{16}$	4		25
95,000	two 4.45×1	T	8.9	A	$1\frac{3}{4}$, 6th	4	H	$1\frac{3}{4}\times1\frac{3}{4}$	4	7. Crosshead pin made thus	26
95,000	two 4.45×1	T	8.9	A	$1\frac{3}{4}$, 6th	4	H	$1\frac{3}{4}\times1\frac{3}{4}$	4		27
95,000	4.45×2	S	8.9	A	$1\frac{7}{8}$, 5th	2	H	$1\frac{7}{8}\times1\frac{43}{64}$	4	*1‡1	28
95,000	4.45×2	S	8.9	A	$1\frac{7}{8}$, 5th	2	H	$1\frac{7}{8}\times1\frac{43}{64}$	4	*1‡1	29
95,000	4.46, $2\frac{1}{2}$	M	11.647	C	$2\frac{1}{2}$, 4th, $\frac{5}{8}$	2	H*	$1\frac{3}{4}\times1\frac{7}{16}$	4	*7	30
95,000	4.46, $2\frac{1}{2}$	M	11.647	C	$2\frac{1}{2}$, 4th, $\frac{5}{8}$	2	H*	$1\frac{3}{4}\times1\frac{7}{16}$	4	*7	31
95,000	4.2, $2\frac{1}{2}$	M	9.878	C	$2\frac{1}{2}$, 6th, $\frac{5}{8}$	2	H	$2\times1\frac{7}{16}$	4		32
95,000	4.45×2	S	8.9	A	$1\frac{7}{8}$, 5th	2	H	$1\frac{1}{2}\times1\frac{43}{64}$	4	*1‡1	33
95,000	4.18, $2\frac{1}{2}$	M	9.747	A	$2\frac{1}{2}$, 6th	2	H	$2\frac{1}{2}\times2\frac{1}{2}$	4		34
95,000	4.18, $2\frac{1}{2}$	M	9.747	A	$2\frac{1}{2}$, 6th	2	H	$2\frac{1}{2}\times2\frac{1}{2}$	4		35
95,000	4.18, $2\frac{1}{2}$	M	9.747	A	$2\frac{1}{2}$, 6th	2	H	$2\frac{1}{2}\times2\frac{1}{2}$	4		36
95,000	4.28×2	S	8.560	A	$1\frac{7}{8}$, 5th	2	H	$1\frac{1}{2}\times1\frac{43}{64}$	4	*1	37
95,000	4 57, $2\frac{1}{2}$	M	12.427	C	$2\frac{1}{2}$, 8th, $\frac{1}{2}$	2	H	$2\frac{1}{2}\times2\frac{1}{2}$	4		38
95,000	4.57, $2\frac{1}{2}$	M	12.427	C	$2\frac{1}{2}$, 8th, $\frac{1}{2}$	2	H	$2\frac{1}{2}\times2\frac{1}{2}$	4		39
95,000	4.57, $2\frac{1}{2}$	M	12.427	C	$2\frac{1}{2}$, 8th, $\frac{1}{2}$	2	H	$2\frac{1}{2}\times2\frac{1}{2}$	4		40
95,000	4.2, $2\frac{1}{2}$	M	9.878	D	$2\frac{1}{2}$, $1\frac{1}{2}$	2	H	2×2	4		41
95,000	4.2, $2\frac{1}{2}$	M	9.878	D	$2\frac{1}{2}$, $1\frac{1}{2}$	2	H	2×2	4		42
95,000	4.2, $2\frac{1}{2}$	M	9.878	D	$2\frac{1}{2}$, $1\frac{1}{2}$	2	H	2×2	4		43
95,000	3.02, 1.68	M	4.946	A	$1\frac{3}{4}$, 5th	2	H	1.55×1.41	4	*8	44
95,000	3.02, 1.68	M	4.946	A	$1\frac{3}{4}$, 5th	2	H	1.55×1.41	4	*8	45
95,000	3.02, 1.68	M	4.946	A	$1\frac{3}{4}$, 5th	2	H	1.55×1.41	4	*8	46
95,000	4.28, 2*	M	11.246	D	$2\frac{1}{2}$, $1\frac{1}{2}$	2	H	$2\frac{1}{2}\times2$	4	*6	47
95,000	4.28, 2*	M	11.246	D	$2\frac{1}{2}$, $1\frac{1}{2}$	2	H	$2\frac{1}{2}\times2$	4	*6	48

PREPARED BY BUREAU OF STEAM ENGINEERING

DESCRIPTION OF LOW PRESSURE PISTONS

FIRST SYLLABLE

S SOLID PISTON

C CORED PISTON

WEB

BOSS

SECOND SYLLABLE

RIM

PACKING SPACE

MATERIAL

K. = CAST STEEL

X. = FORGED STEEL

R. = CAST IRON

T. = COMPOSITION

	NAME OF SHIP	DIAM. OF CYL.	TOTAL HEIGHT OF PISTON	LEAST THICKNESS OF WEB	TANGENT OF ANGLE BETWEEN BASE OF CONE AND SLANT HEIGHT TOP	TANGENT OF ANGLE BETWEEN BASE OF CONE AND SLANT HEIGHT BOTTOM	CROSS SECTION OF RIM INCLUDING FOLLOWER THICKNESS AND HEIGHT t" × h"	DESCRIPTION OF PISTON	FINISHED WEIGHT OF PISTON	REMARKS
1	*Ericsson*	30	5¾	1/16	.1183	.0874	1/2 × 2¾	SEM-DOX	162.25	
2	*Foote*	22	6	¼	.2962	.1405	¼ × 2¾	SEM-DIK	83	
3	*Rodgers*	22	6	¼	.2962	.1405	¼ × 2¾	SEM-DIK	83	
4	*Winslow*	22	6	¼	.2962	.1405	¼ × 2¾	SEM-DIK	83	
5	*Porter*	25	5¼	1/16	.2400	.1583	1 × 2	SEM-POK	...	
6	*Dupont*	25	5¼	1/16	.2400	.1583	1 × 2	SEM-POK	...	
7	*Rowan*	25½	7	1/16	.2216	.1673	1 × 2½	SEM-DOX	124	
8	*Dahlgren*	37·37	9·9	.38	.2962*	.2308	.43 × 3.49	SIM-POX	...	
9	*T. A. M. Craven*	37·37	9·9	.38	.2962*	.2308	.43 × 3.49	SIM-POX	...	
10	*Morris*	25	4½	3/16	.2125†	.1763	3/16 × 1½	SIM-POK	75	
11	*Talbott*	25	4½	3/16	.2125†	.1763	3/16 × 1½	SIM-POK	73	
12	*Gwin*	25	4½	3/16	.2125†	.1763	3/16 × 1½	SIM-POK	73	
13	*Davis*	22½	5¾	¼	.1673	.1494	1 × 2½	SEM-DOK	111.75	
14	*Fox*	22½	5¾	¼	.1673	.1494	1 × 2½	SEM-DOK	111.75	
15	*McKee*	22	6	1/16	.1989	.1763	3/16 × 2½	SEM-DOK	82	
16	*Mackenzie*	22	6	¼	.2034	.1673	1 × 2½	SEM-DIK	81	
17	*Farragut*	30	9	3/16	.3153‡	.2400	1/16 × 3	SIM-DIK	184.25	
18	*Bailey*	32	9	¼	.3346	.1943	1 × 3	SEM-DOX	...	
19	*Stringham*	34	9¼	1/16	.2679	.2034	1 × 3	SEM-DIK	...	
20	*Goldsborough*	35½	8¾	1/16	.2308	.1989	1 × 3	SEM-DIK	...	
21	*Nicholson*	28	7	1/16	.1673	.1316	1¼ × 3	SEM-DIX	...	
22	*O'Brien*	28	7	1/16	.1673	.1316	1¼ × 3	SEM-DIX	...	
23	*Blakely*	25½	6¾	1/16	.3443	.2962	1 × 2½	SEM-PIX	...	
24	*DeLong*	25½	6¾	1/16	.3443	.2962	1 × 2½	SEM-PIX	...	
25	*Lawrence*	34	9¼	¼	.3738	.3249	1 1/16 × 2½	SEM-DOX	...	
26	*Macdonough*	34	9¼	¼	.3738	.3249	1 1/16 × 2½	SEM-DOX	...	
27	*Stewart*	38	9¼	1/16	.2216	.1763	1¼ × 3	SEM-DIX	...	
28	*Wilkes*	25½	6¾	1/16	.1763	.1494	1 × 2½	SEM-DIX	...	
29	*Tingley*	25½	6¾	¼	.2962	.2586	1/16 × 2½	SEM-PIX	...	
30	*Bainbridge*	38	9¼	¼	.2080	.1405	1¼ × 3	SEM-DIX	...	
31	*Chauncey*	38	9¼	¼	.2080	.1405	1¼ × 3	SEM-DIX	...	
32	*Barry*	38	9¼	¼	.2080	.1405	1¼ × 3	SEM-DIX	...	
33	*Whipple*	37	10 1/16	1/16	.4091	.3249	1¼ × 3	SEM-PIX	...	
34	*Worden*	37	10 1/16	1/16	.4091	.3249	1¼ × 3	SEM-PIX	...	
35	*Truxtun*	37	10 1/16	1/16	.4091	.3249	1¼ × 3	SEM-PIX	...	
36	*Perry*	38	10	1/16	.2773**	.2308	3/16 × 3	SIM-DIX	...	
37	*Preble*	38	10	1/16	.2773**	.2308	3/16 × 3	SIM DIX	...	
38	*Paul Jones*	38	10	1/16	.2773**	.2308	3/16 × 3	SIM-DIX	...	
39	*Hopkins*	34	9¼	1/16	.2679	.2101	1 × 3	SEM-DIK	...	
40	*Hull*	34	9¼	1/16	.2679	.2101	1 × 3	SEM-DIK	...	
41	*Barney*	37·37	9 9/32	.50	.2679§	.2400	.795 × 3.49	SIM-POX	...	
42	*Biddle*	37·37	9·9/32	.50	.2679§	.2400	.795 × 3.49	SIM-POX	...	
43	*Bagley*	37·37	9·9/32	.50	.2679§	.2400	.795 × 3.49	SIM-POX	...	
44	*Shubrick*	25½	6¼	¼	.2262	.1694	3/16 × 2¼	SEM-DIX	136	
45	*Thornton*	25½	6¼	¼	.2262	.1694	3/16 × 2¼	SEM-DIX	136	
46	*Stockton*	25½	6¼	¼	.2262	.1694	3/16 × 2¼	SEM-DIX	136	
47	*Dale*	38	9¼	1/16	.5949	.5317	1¼ × 3	SEM-DIX	...	
48	*Decatur*	38	9¼	1/16	.5949	.5317	1¼ × 3	SEM-DIX	...	

*Angle increases from minimum at rim to maximum at hub, tangent of angle at hub = .4296.

†Angle increases from minimum at rim to maximum at hub, tangent of angle at hub = .6618.

‡Angle increases from minimum at rim to maximum at hub, tangent of angle at hub = 1.2349.

**Angle varies from minimum at rim to maximum at hub, tangent of angle at hub = .8391.

§Angle varies from minimum at rim to maximum at hub, tangent of angle at hub = 4504.

TABLE III.

CRANK SHAFTS

ABLE

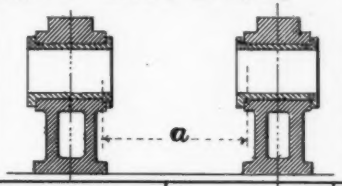
MATERIAL
K. = CAST STEEL
X. = FORGED STEEL
R. = CAST IRON
T. = COMPOSITION

S

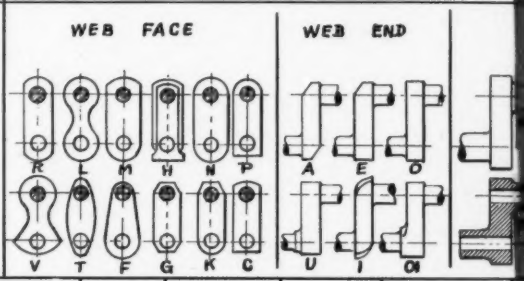
LENGTH BETWEEN BEARINGS

AFTER ENGINE

THIS DISTANCE IS ASSUMED IN ALL CASES TO BE 1 GREATER THAN THE DISTANCE BETWEEN THE BEDPLATE CASTING AS SHOWN.



DESCRIPTION OF CRANK



DIAMETER OF SHAFT		DIMENSIONS OF WEB		L	LENGTH BETWEEN BEARINGS	INDICATED HORSE POWER	REVOLUTIONS PER MIN.	DESCRIPTION
OUTSIDE	HOLE	END	FACE	THROW OF CRANK	a	HP	R	
5	2½	3½	5½	8	18½	915.99	385.80	RENT
4½	3½	3½	6	8	16½	1,000	420	CANT
4½	3½	3½	6	8	16½	1,177.47	400.96	CANT
4½	3½	3½	6	8	16½	1,000	420	CANT
7½	4	4½	11	8	33½	1,600	395	PENT
7½	4	4½	11	8	33½	1,600	395	PENT
6½	3½	4½	7	9	20½	1,600	395	NANT
6.80	3.36	3.78	8.65	10.5	26.74	1,679	300.20	HENT*
6.80	3.36	3.78	8.65	10.5	26.74	1,808.80	339.10	HENT*
5½	---	3½	6½	6½	22½	875	430	COLT*
5½	---	3½	6½	6½	22½	850	400	COLT*
5½	---	3½	6½	6½	22½	850	400	COLT*
5	2½	3½	6	7½	17½	875	395	GANT
5	2½	3½	6	7½	17½	875	395	GANT
5	---	3½	5½	8	17	850	350	PELT
5½	3	3½	6	8	17½	850	350	RANT
6½	4	4	8	9	21	2,800	400	PENT
7	4	4	8½	9	26	2,800	400	PENT
7½	4	4½	8½	9	24½	3,600	240	KENT
7½	3½	4	8½-7½†	10	28½	2,925	360	FENT
7	4	4½	8½	9	19½	1,750	350	GANT
7	4	4½	8½	9	19½	1,750	350	GANT
6½	4	4½	8	9	23½	1,500	350	RENT
6½	4	4½	8	9	23½	1,500	350	RENT
8	4	4½	10	10	24	4,200	360	NANT
8	4	4½	10	10	24	4,200	360	NANT
8½	4½	4½	10½	11	23½	4,000	300	NANT
6½	4	3½	8	9	22½	1,500	350	RENT
6½	4	3½	8	9	22½	1,500	350	PENT
8½	4½	4½	10½	11	24½	4,000	327	NANT
8½	4½	4½	10½	11	24½	4,000	327	NANT
8½	4½	4½	10½	11	24½	4,000	327	NANT
8½	4½	4½	10½	11	27½	4,150	360	NANT
8½	4½	4½	10½	11	27½	4,150	360	NANT
8½	4½	4½	10½	11	27½	4,150	360	NANT
8½	4½	4½	10½	11	30	4,000	327	NANT
8½	4½	4½	10½	11	30	4,000	327	NANT
8½	4½	4½	10½	11	30	4,000	327	NANT
7½	4	4½	9	9	26	3,600	400	KENT
7½	4	4½	9	9	26	3,600	400	KENT
6.80	3.36	3.99	8.65	10.5	26.74	2,143	301.8	HENT
6.80	3.36	3.99	8.65	10.5	26.74	2,112.5	325.2	HENT
6.80	3.36	3.99	8.65	10.5	26.74	2,100	320	HENT
6½	4	3½	8	9	23½	1,500	350	NANT
6½	4	3½	8	9	23½	1,500	350	NANT
6½	4	3½	8	9	23½	1,500	350	NANT
8½	4½	4½	10½	11	27½	4,000	327	NANT
8½	4½	4½	10½	11	27½	4,000	327	NANT

nimum at rim to
of angle at hub

nimum at rim to
of angle at hub

nimum at rim to
of angle at hub

m at rim to maxi-
at hub = .8391.

n at rim to maxi-
at hub = 4504.

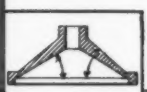
TABLE III.

DESCRIPTION OF LOW PRESSURE PISTONS

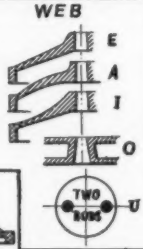
FIRST SYLLABLE

S SOLID PISTON

C CORED PISTON



WEB



BOSS

SECOND SYLLABLE

RIM

PACKING SPACE

MATERIAL

K. = CAST STEEL

X. = FORGED STEEL

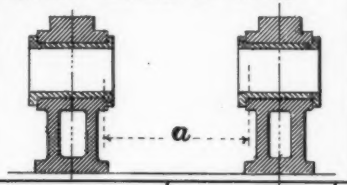
R. = CAST IRON

T. = COMPOSITION

LENGTH BETWEEN BEARINGS

AFTER ENGINE

THIS DISTANCE IS ASSUMED IN ALL CASES TO BE 1 GREATER THAN THE DISTANCE BETWEEN THE BEDPLATE CASTING AS SHOWN.



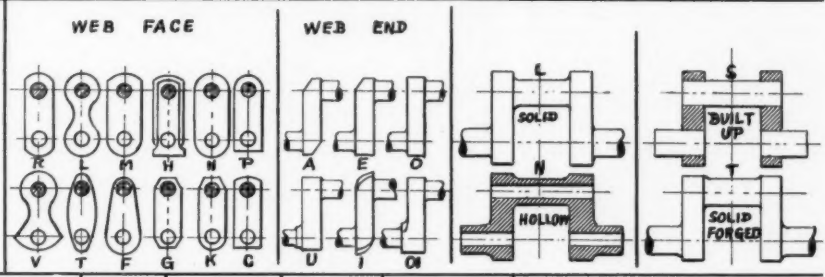
TANGENT OF ANGLE BETWEEN BASE OF CONE AND SLANT HEIGHT		CROSS SECTION OF RIM INCLUDING FOLLOWER	DESCRIPTION OF PISTON	FINISHED WEIGHT OF PISTON	REMARKS	DIAMETER OF SHAFT		DIMENSIONS OF WEB		TH
TOP	BOTTOM	THICKNESS AND HEIGHT $t'' \times h''$				OUTSIDE	HOLE	END	FACE	
.1183	.0874	$\frac{13}{16} \times 2\frac{1}{2}$	SEM-DOX	162.25	*Angle increases from minimum at rim to maximum at hub, tangent of angle at hub = .4296.	5	$2\frac{1}{2}$	$3\frac{1}{4}$	$5\frac{1}{2}$	
.2062	.1405	$\frac{13}{16} \times 2\frac{1}{2}$	SEM-DIK	83		$4\frac{1}{2}$	$3\frac{1}{2}$	$3\frac{1}{4}$	6	
.2062	.1405	$\frac{13}{16} \times 2\frac{1}{2}$	SEM-DIK	83		$4\frac{1}{2}$	$3\frac{1}{2}$	$3\frac{1}{4}$	6	
.2062	.1405	$\frac{13}{16} \times 2\frac{1}{2}$	SEM-DIK	83		$4\frac{1}{2}$	$3\frac{1}{2}$	$3\frac{1}{4}$	6	
.2400	.1583	1×2	SEM-POK	...	†Angle increases from minimum at rim to maximum at hub, tangent of angle at hub = .6618.	$7\frac{1}{2}$	4	$4\frac{1}{2}$	11	
.2400	.1583	1×2	SEM-POK	...		$7\frac{1}{2}$	4	$4\frac{1}{2}$	11	
.2216	.1673	$1 \times 2\frac{1}{2}$	SEM-DOX	194		$6\frac{1}{2}$	$3\frac{1}{2}$	$4\frac{1}{2}$	7	
.2962*	.2308	$.43 \times 3.49$	SIM-POX	...		6.80	3.36	3.78	8.65	
.2962*	.2308	$.43 \times 3.49$	SIM-POX	...	‡Angle increases from minimum at rim to maximum at hub, tangent of angle at hub = 1.2349.	6.80	3.36	3.78	8.65	
.2125†	.1763	$\frac{13}{16} \times 1\frac{1}{2}$	SIM-POK	73		$5\frac{1}{2}$	...	$3\frac{1}{4}$	$6\frac{1}{2}$	
.2125†	.1763	$\frac{13}{16} \times 1\frac{1}{2}$	SIM-POK	73		$5\frac{1}{2}$	...	$3\frac{1}{4}$	$6\frac{1}{2}$	
.2125†	.1763	$\frac{13}{16} \times 1\frac{1}{2}$	SIM-POK	73		$5\frac{1}{2}$	...	$3\frac{1}{4}$	$6\frac{1}{2}$	
.1673	.1494	$1 \times 2\frac{1}{2}$	SEM-DOK	111.75	**Angle varies from minimum at rim to maximum at hub, tangent of angle at hub = .8391.	5	$2\frac{1}{2}$	$3\frac{1}{4}$	6	
.1673	.1494	$1 \times 2\frac{1}{2}$	SEM-DOK	111.75		5	$2\frac{1}{2}$	$3\frac{1}{4}$	6	
.1989	.1763	$\frac{13}{16} \times 2\frac{1}{2}$	SEM-DOK	82		5	...	$3\frac{1}{4}$	$5\frac{1}{2}$	
.2034	.1673	$1 \times 2\frac{1}{2}$	SEM-DIK	81	§Angle varies from minimum at rim to maximum at hub, tangent of angle at hub = 4504.	$5\frac{1}{2}$	3	$3\frac{1}{4}$	6	
.3153‡	.2400	$\frac{5}{16} \times 3$	SIM-DIK	184.25		$6\frac{1}{2}$	4	4	8	
.3346	.1943	1×3	SEM-DOX	...		7	4	4	$8\frac{1}{2}$	
.2679	.2034	1×3	SEM-DIK	...		$7\frac{1}{2}$	4	$4\frac{1}{2}$	$8\frac{1}{2}$	
.2308	.1989	1×3	SEM-DIK	...		$7\frac{1}{2}$	$3\frac{1}{2}$	4	$8\frac{1}{2}$–$7\frac{1}{2}$††	
.1673	.1316	$1\frac{1}{2} \times 3$	SEM-DIX	...		7	4	$4\frac{1}{2}$	$8\frac{1}{2}$	
.1673	.1316	$1\frac{1}{2} \times 3$	SEM-DIX	...		7	4	$4\frac{1}{2}$	$8\frac{1}{2}$	
.3443	.2962	$1 \times 2\frac{1}{2}$	SEM-PIX	...		$6\frac{1}{2}$	4	$4\frac{1}{2}$	8	
.3443	.2962	$1 \times 2\frac{1}{2}$	SEM-PIX	...		$6\frac{1}{2}$	4	$4\frac{1}{2}$	8	
.3738	.3249	$1\frac{1}{16} \times 2\frac{1}{2}$	SEM-DOX	...		8	4	$4\frac{1}{2}$	10	
.3738	.3249	$1\frac{1}{16} \times 2\frac{1}{2}$	SEM-DOX	...		8	4	$4\frac{1}{2}$	10	
.2216	.1763	$1\frac{1}{2} \times 3$	SEM-DIX	...		$8\frac{1}{2}$	$4\frac{1}{2}$	$4\frac{1}{2}$	$10\frac{1}{2}$	
.1763	.1494	$1 \times 2\frac{1}{2}$	SEM-DIX	...		$6\frac{1}{2}$	4	$3\frac{1}{2}$	8	
2962	.2586	$\frac{13}{16} \times 2\frac{1}{2}$	SEM-PIX	...		$6\frac{1}{2}$	4	$3\frac{1}{2}$	8	
.2080	.1405	1×3	SEM-DIX	...		$8\frac{1}{2}$	$4\frac{1}{2}$	$4\frac{1}{2}$	$10\frac{1}{2}$	
.2080	.1405	1×3	SEM-DIX	...		$8\frac{1}{2}$	$4\frac{1}{2}$	$4\frac{1}{2}$	$10\frac{1}{2}$	
.2080	.1405	1×3	SEM-DIX	...		$8\frac{1}{2}$	$4\frac{1}{2}$	$4\frac{1}{2}$	$10\frac{1}{2}$	
.4091	.3249	1×3	SEM-PIX	...		$8\frac{1}{2}$	$4\frac{1}{2}$	$4\frac{1}{2}$	$10\frac{1}{2}$	
.4091	3249	1×3	SEM-PIX	...		$8\frac{1}{2}$	$4\frac{1}{2}$	$4\frac{1}{2}$	$10\frac{1}{2}$	
.4091	.3249	1×3	SEM-PIX	...		$8\frac{1}{2}$	$4\frac{1}{2}$	$4\frac{1}{2}$	$10\frac{1}{2}$	
.2773**	.2308	$\frac{13}{16} \times 3$	SIM-DIX	...		$8\frac{1}{2}$	$4\frac{1}{2}$	$4\frac{1}{2}$	$10\frac{1}{2}$	
.2773**	.2308	$\frac{13}{16} \times 3$	SIM DIX	...		$8\frac{1}{2}$	$4\frac{1}{2}$	$4\frac{1}{2}$	$10\frac{1}{2}$	
.2773**	.2308	$\frac{13}{16} \times 3$	SIM-DIX	...		$8\frac{1}{2}$	$4\frac{1}{2}$	$4\frac{1}{2}$	$10\frac{1}{2}$	
.2679	.2101	1×3	SEM-DIK	...		7	4	$4\frac{1}{2}$	9	
.2679	.2101	1×3	SEM-DIK	...		7	4	$4\frac{1}{2}$	9	
.2679§	.2400	$.795 \times 3.49$	SIM-POX	...		6.80	3.36	3.99	8.65	
.2679§	.2400	$.795 \times 3.49$	SIM-POX	...		6.80	3.36	3.99	8.65	
.2679§	.2400	$.795 \times 3.49$	SIM-POX	...		6.80	3.36	3.99	8.65	
.2262	.1694	$1 \times 2\frac{1}{2}$	SEM-DIX	136		$6\frac{1}{2}$	4	$3\frac{1}{2}$	8	
.2262	.1694	$1 \times 2\frac{1}{2}$	SEM-DIX	136		$6\frac{1}{2}$	4	$3\frac{1}{2}$	8	
.2262	.1694	$1 \times 2\frac{1}{2}$	SEM-DIX	136		$6\frac{1}{2}$	4	$3\frac{1}{2}$	8	
.5949	.5317	1×3	SEM-DIX	...		$8\frac{1}{2}$	$4\frac{1}{2}$	$4\frac{1}{2}$	$10\frac{1}{2}$	
.5949	.5317	1×3	SEM-DIX	...		$8\frac{1}{2}$	$4\frac{1}{2}$	$4\frac{1}{2}$	$10\frac{1}{2}$	

CRANK SHAFTS

BEARINGS

CASES TO BE ETWEEN THE OWN.

DESCRIPTION OF CRANK



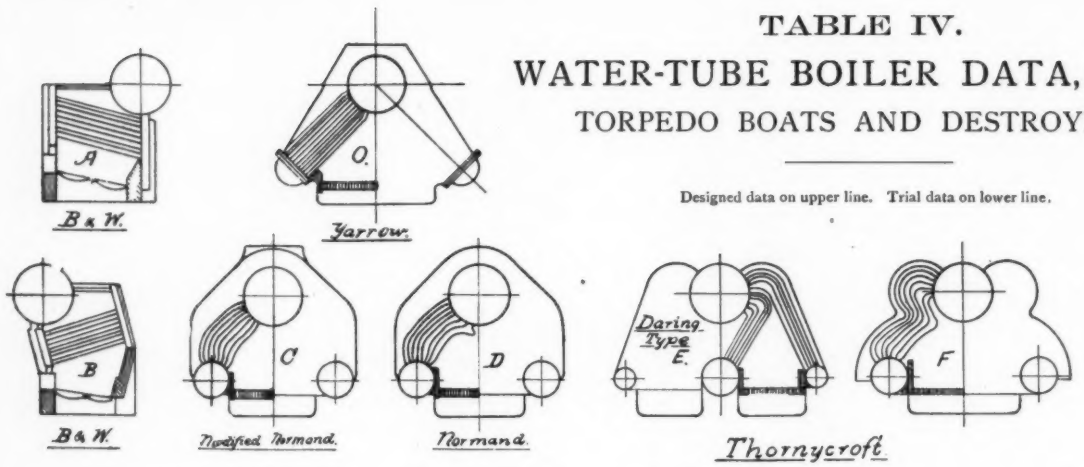
NS OF WEB FACE	L THROW OF CRANK	LENGTH BETWEEN BEARINGS a	INDICATED HORSE POWER HP	REVOLUTIONS PER MIN. R	DESCRIPTION	REMARKS.	
5⅛	8	18½	915.99	385.80	RENT	*Counter balance.	1
6	8	16½	1,000	420	CANT		2
6	8	16½	1,177.47	400.96	CANT	†Face of web between pins varies from 8¼ inches to 7⅛ inches.	3
6	8	16½	1,000	420	CANT		4
11	8	33⅛	1,600	395	PENT		5
11	8	33⅛	1,600	395	PENT		6
7	9	20½	1,600	395	NANT		7
8.65	10.5	26.74	1,679	300.20	HENT*		8
8.65	10.5	26.74	1,808.80	339.10	HENT*		9
6½	6½	22½	875	430	COLT*		10
6½	6½	22½	850	400	COLT*		11
6½	6½	22½	850	400	COLT*		12
6	7½	17½	875	395	GANT		13
6	7½	17½	875	395	GANT		14
5⅛	8	17	850	350	PELT		15
6	8	17⅞	850	350	RANT		16
8	9	21	2,800	400	PENT		17
8½	9	26	2,800	400	PENT		18
8½	9	24½	3,600	240	KENT		19
8¼-7⅛†	10	28⅞	2,925	360	FENT		20
8½	9	19½	1,750	350	GANT		21
8½	9	19½	1,750	350	GANT		22
8	9	23½	1,500	350	RENT		23
8	9	23½	1,500	350	RENT		24
10	10	24	4,200	360	NANT		25
10	10	24	4,200	360	NANT		26
10½	11	23⅞	4,000	300	NANT		27
8	9	22½	1,500	350	RENT		28
8	9	22½	1,500	350	PENT		29
10½	11	24⅞	4,000	327	NANT		30
10½	11	24⅞	4,000	327	NANT		31
10½	11	24⅞	4,000	327	NANT		32
10⅞	11	27⅞	4,150	360	NANT		33
10⅞	11	27⅞	4,150	360	NANT		34
10⅞	11	27⅞	4,150	360	NANT		35
10½	11	30	4,000	327	NANT		36
10½	11	30	4,000	327	NANT		37
10½	11	30	4,000	327	NANT		38
9	9	26	3,600	400	KENT		39
9	9	26	3,600	400	KENT		40
8.65	10.5	26.74	2,143	301.8	HENT		41
8.65	10.5	26.74	2,112.5	325.2	HENT		42
8.65	10.5	26.74	2,100	320	HENT		43
8	9	23½	1,500	350	NANT		44
8	9	23½	1,500	350	NANT		45
8	9	23½	1,500	350	NANT		46
10½	11	27⅞	4,000	327	NANT		47
10½	11	27⅞	4,000	327	NANT		48

TABLE IV.

WATER-TUBE BOILER DATA, U.

TORPEDO BOATS AND DESTROYER

Designed data on upper line. Trial data on lower line.

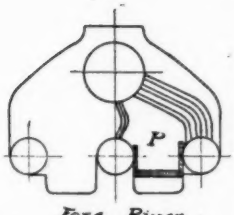


Number.	Name of ship.	Name of boiler.	Number of boilers.	Type.	Steam pressure.	Design I.H.P.	Actual I.H.P.	Air pressure.	Closed fire rooms.	Size of boiler from face of boiler to overhang at back. Length.	Breadth.	Greatest height.	Furnaces. Grate. Length.	Width.	G.S. Grate surface in one boiler.	T.G.S. Total grate surface in all boilers.	Tubes. Number.	Diameter.
1	*Cushing*	Thornycroft.	2	F	250	1,600	1,720	2.7	b	9-0	8-4	8-9	7-6	5-1½	38.3	76.6	760	1½
			"	"					b								190	1½
2	*Ericsson*	Thornycroft.	2	F	250	1,800	1,582	5	b	10-0	9-6	9-3	7-6	5-8	42.5	85	1,032	1½
			"	"					b								170	1½
3	*Foote*	Mosher.	2	G	250	2,000	2,400	4.18	b	9-5	9-9	8-6	7-6	6-4	47.5	95	1,098	1½
4	*Rodgers.*	Mosher.	2	G	250	2,000			b	9-5	9-9	8-6	7-6	6-4	47.5	95	1,098	1½
			"	"					b								204	1½
5	*Winslow*	Mosher.	2	G	250	2,000			b	9-5	9-9	8-6	7-6	6-4	47.5	95	1,098	1½
			"	"					b								204	1½
6	*Porter*	Mod. Normand.	3	C	250	3,200			b	9-9	10-7	11-0	8-0½	6-8	53.53	160.6	1,445	1½
			"	"					b									
7	*Dupont*	Mod. Normand.	3	C	250	3,200			b	9-9	10-7	11-0	8-0½	6-8	53.53	160.6	1,445	1½
			"	"					b									
8	*Rowan*	Mosher.	3	G	250	3,200		2.9	b	9-0	10-0	8-4	7-6½	6-4	47 8	143.4	1,098	1½
			"	"					b								204	1½
9	*Dahlgren*	Normand.	2	D	230	4,200		5	b	11-6	10-7	11-5	9-6½	6-2½	59⅜	118¾	1,374	1 1/16
			"	"					b								178	1 1/16
10	*T. A. M. Craven.*	Normand.	2	D	230	4,200			b	11-6	10-7	11-5	9-6½	6-2½	59⅜	118¾	1,374	1 1/16
			"	"					b								178	1 1/16
11	*Farragut*	Thornycroft.	3	E	240	5,600		4½	b	12-9	13-0	10-9	7-0¾	4-8	65.3	109.6	974	1½
			"	"					b								546	1½
12	*Davis*	Thornycroft.	2	F	250	1,750		2	b	10-0	9-6	9-2	7-6	5-10½	44	88	854	1½
			"	"					b								170	1½
13	*Fox*	Thornycroft.	2	F	250	1,750		2	b	10-0	9-6	9-2	7-6	5-10½	44	88	854	1½
			"	"					b								170	1½
14	*Morris*	Mod. Normand.	2	C	250	1,750			b	8-9	9-4¾	9-0	7-1	5-8	40	80	1,200	1½
			"	"					b									
15	*Talbot*	Mod. Normand.	1	C	225	850		1.75	b	9-9	8-4½	8-1⅞	8-0	4-9½	38	38	1,275	1½
16	*Gwin*	Mod. Normand.	1	C	225	850		3.3	b	9-9	8-4½	8-1⅞	8-0	4-9½	38	38	1,275	1½
			"	"					b									
17	*Mackenzie*	Thornycroft.	2	F	250	850		2.94	b	6-9	7-2	7-6	4-10½	4-1½	20	40	538	1
18	*McKee*	Thornycroft	2	F	250	850			b	6-9	7-2	7-6	4-10½	4-1½	20	40	538	1
			"	"					b								126	1⅛
19	*Stringham*	Thornycroft.	4	E	240	7,200		3	b	10-9	12-10	10-10	7-0	4-6	63	252	1,480	1
			"	"					b								368	1⅛
20	*Goldsborough*	Thornycroft.	3	E	250	5,850			b	11-2	13-7	10-5	7-2½	5-0	72	216	1,396	1½
			"	"					b								384	1½
21	*Bailey*	Seabury.	4	M	245	5,600			b	11-6	10-6	12-0	9-0	6-3	56¼	225	972	1
			"	"					b								300	1½
22	*Bagley*	Normand.	2	D	230	4,200			b	11-2	10-6	11-6	9-6	6-3	59⅜	118¾	1,552	1 3/16
			"	"					b									
23	*Barney*	Normand.	2	D	230	4,200			b	11-2	10-6	11-6	9-6	6-3	59⅜	118¾	1,552	1 3/16
24	*Biddle*	Normand.	2	D	230	4,200		6 84	b	11-2	10-6	11-6	9-6	6-3	59⅜	118¾	1,552	1 3/16
			"	"					b									
25	*Blakely*	Normand.	3	D	250	3,000			b	8-10	10-5	10-0	7-8	6-6	50	150	1,244	1½
			"	"					b									
26	*DeLong*	Normand.	3	D	250	3,000			b	8-10	10-5	10-0	7-8	6-6	50	150	1,244	1½
			"	"					b									
27	*Nicholson*	Mosher.	3	G	250	3,500			b	8-8	10-11	8-9	7-0	7-6	52 5	157.5	1,340	1½
28	*O'Brien*	Mosher.	3	G	250	3,500			b	8-8	10-11	8-9	7-0	7-6	52.5	157.5	1,340	1½
			"	"					b									
29	*Shubrick*	Thornycroft.	3	F	250	3,000			b	8-4	10-8	10-3	6-9	6-9	45.67	137	776	1½
30	*Stockton*	Thornycroft.	3	F	250	3,000			b	8-4	10-8	10-3	6-9	6-9	45.67	137	776	1½
			"	"					b								140	1½
31	*Thornton*	Thornycroft.	3	F	250	3,000			b	8-4	10-8	10-3	6-9	6-9	45.67	137	776	1½
			"	"					b								140	1½

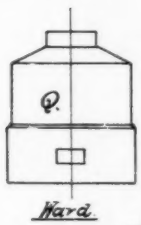
TA, U. S. N.

ROYERS.

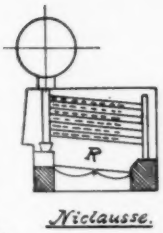
r line.



Fore River.



Ward



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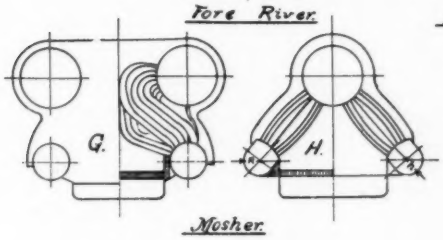
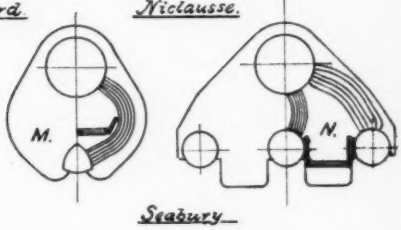


Mosher



Seabury

	Tubes in one boiler.					Heating surface.				Drums.					Ratios.				
				Downtake.				H.S.	T.H.S.	Steam.		Water.							
	Number.	Diameter.	B.W.G.	Number.	Diameter.	Tubes in square feet.	All other heating surface in square feet.	One boiler.	All boilers.	Diameter.	Length.	Diameter.	Length.	Number.	H.S. / G.S.	T.H.S. / I.H.P.	I.H.P. / T.G.S.	Tubes. / Downtake.	Number.
	760	1¾	11	2	7½	2,37	...	2,375	4,750	26½	131	14	129	2	62	2.96	20.88	6.48	1
	190	1¾	10	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
	1,032	1¾	12	2	8	2,349	...	2,349	4,698	30	147	14	137	2	55.27	2.61	21.17	8.08	2
	170	1¾	10	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
	1,098	1¾	12	186	1¾	2,630	...	2,630	5,260	2-22	131	14	117	2	55.36	2.63	21	6.89	3
	204	1¾	10	×	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
	1,098	1¾	12	186	1¾	2,630	...	2,630	5,260	2-22	131	14	117	2	55.36	2.63	21	6.89	4
	204	1¾	10	×	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
	1,098	1¾	12	186	1¾	2,630	...	2,630	5,260	2-22	131	14	117	2	55.36	2.63	21	6.89	5
	204	1¾	10	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
	1,445	1¾	15	2	9⅛	2,762 6	...	2,762 6	8,288	32	112	16	105½	2	51.6	2.59	19.92	7.5	6
	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
	1,445	1¾	15	2	9⅛	2,762.6	...	2,762.6	8,288	32	112	16	105½	2	51.6	2.59	19.92	7.5	7
	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
	1,098	1¾	12	186	1¾	2,606	24	2,630	7,890	2-22	124	14	114	2	55	2.46	22.3	6.89	8
	204	1¾	10	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
	1,374	1 15/16	13	2	1.18	2,776	...	2,776	5,552	35.43	154	15.74	144	2	46.75	1.32	35.37	7.52	9
	178	1 15/16	11	2	10	...	...	...	...	...	...	...	...	...	...	...	...	...	
	1,374	1 15/16	13	2	1.18	2,776	...	2,776	5,552	35.43	154	15 74	144	2	46.75	1.32	35.37	7 52	10
	178	1 15/16	11	2	10	...	...	...	...	...	...	...	...	...	...	...	...	...	
	974	1½	12	13	4	3,304	...	3,304	9,912	37	162	18	153	1	50.59	1.77	28.57	6.78	11
	546	1½	...	...	...	...	...	...	...	...	...	7	...	2	...	...	...	...	
	854	1½	13	2	8	2,381.5	...	2,381.5	4,763	30	148	16	134½	2	54.1	2.72	19.88	7.18	12
	170	1½	11	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
	854	1½	13	2	8	2,381 5	...	2,381.5	4,763	30	148	16	134½	2	54.1	2.72	19 88	7.18	13
	170	1½	11	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
	1,200	1¾	15	2	9.57	2,002	...	2,002	4,004	32	114	16	105	2	50	2.30	21.8	6.31	14
	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
	1,275	1¾	15	2	9.57	1,870	...	1,870	1,870	32	124	16	118	2	49.2	2.20	22 37	6.71	15
	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
	1,275	1¾	15	2	9 57	1,870	...	1,870	1,870	32	124	16	118	2	49 2	2.20	22.37	6.71	16
	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
	538	...	...	2	6½	1,084	...	1,084	2,168	20	102½	10½	94½	2	54.2	2.55	21.2	5.34	17
	126	1½	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
	538	1½	13	2	6½	1,147	...	1,147	2,294	20	100	10½	94	2	57.3	2.69	21.2	5.34	18
	126	1½	11	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
	1,480	1	12	12	4	4,005	...	4,005	16,020	31	142½	18	132	1	63.57	2 22	28.57	8.11	19
	368	1½	11	...	...	...	...	...	...	...	...	7½	...	2	...	...	...	...	
	1,396	1½	11	14	4	4,500	...	4,500	13,500	37	155½	18	137	1	62.5	2.30	27.08	8.07	20
	384	1½	11	...	...	...	...	...	...	...	...	6½	...	2	...	...	...	...	
	972	1	12	4	5⅛	3,300	...	3,300	13,200	36	145½	18×23½	142	1	58.6	2 35	24.88	6 55	21
	300	1½	11	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
	1,552	1 1/16	11	2	1.18	2,776	...	2,776	5,552	35.43	153	15.74	144	2	46 75	1.32	35.36	6.59	22
	...	...	...	2	10	...	...	...	...	...	...	...	...	...	...	...	...	...	
	1,552	1 1/16	11	2	1.18	2,776	...	2,776	5,552	35.43	153	15 74	144	2	46.75	1 32	35.36	6.59	23
	...	...	...	2	10	...	...	...	...	...	...	...	...	...	...	...	...	...	
	1,552	1 1/16	11	2	1.18	2,776	...	2,776	5,552	35 43	153	15.74	144	2	46 75	1.32	35.36	6.59	24
	...	...	...	2	10	...	...	...	...	...	...	...	...	...	...	...	...	...	
	1,244	1½	11	2	8¼	2,525	...	2,525	7,575	32	129	16	122	2	50.5	2.52	20	6 66	25
	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
	1,244	1½	11	2	8¼	2,525	...	2,595	7,575	32	129	16	122	2	50.5	2.52	20	6.66	26
	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
	1,340	1½	11	164	1½	2,802	...	2,802	8,406	2-24	116	16	108	2	53 37	2.4	22.2	8.17	27
	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
	1,340	1½	11	164	1½	2,802	...	2,802	8,406	2-24	116	16	108	2	53.37	2.4	22.2	8.17	28
	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
	776	1½	11	2	7	2,516	...	2,516	7,548	30	118	16	112	2	55	2.51	21.9	7.65	29
	140	1½	11	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
	776	1½	11	2	7	2,51	...	2,516	7.548	30	118	16	112	2	55	2.51	21.9	7.65	30
	140	1½	11	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	

Mosher

Seabury

Thornycroft

Number.	Name of ship.	Name of boiler.	Number of boilers.	Type.	Steam pressure.	Design I.H.P.	Actual I.H.P.	Air pressure.	Closed fire rooms.	Size of boiler from face of boiler to overhang at back. Length.	Breadth.	Greatest height.	Furnaces. Grate. Length.	Grate. Width.	G.S. Grate surface in one boiler.	T.G.S. Total grate surface in all boilers.	Tubes. Number.	Diameter.
1	*Cushing*	Thornycroft.	2	F	250	1,600	1,720	2.7	b	9-0	8-4	8-9	7-6	5-1½	38.3	76.6	760	1
2	*Ericsson*	Thornycroft.	2	F	250	1,800	1,582	5	b	10-0	9-6	9-3	7-6	5-8	42.5	85	1,032	1
3	*Foote*	Mosher.	2	G	250	2,000	2,400	4.18	b	9-5	9-9	8-6	7-6	6-4	47.5	95	1,098	1
4	*Rodgers*	Mosher.	2	G	250	2,000	...	...	b	9-5	9-9	8-6	7-6	6-4	47.5	95	1,098	1
5	*Winslow*	Mosher.	2	G	250	2,000	...	...	b	9-5	9-9	8-6	7-6	6-4	47.5	95	1,098	1
6	*Porter*	Mod. Normand.	3	C	250	3,200	...	...	b	9-9	10-7	11-0	8-0½	6-8	53.53	160.6	1,445	1
7	*Dupont*	Mod. Normand.	3	C	250	3,200	...	...	b	9-9	10-7	11-0	8-0½	6-8	53.53	160.6	1,445	1⅛
8	*Rowan*	Mosher.	3	G	250	3,200	...	2.9	b	9-0	10-0	8-4	7-6½	6-4	47 8	143.4	1,098	1⅛
9	*Dahlgren*	Normand.	2	D	230	4,200	...	5	b	11-6	10-7	11-5	9-6½	6-2⅝	59⅜	118¾	1,374	1⅛
10	*T. A. M. Craven*	Normand.	2	D	230	4,200	...	...	b	11-6	10-7	11-5	9-6½	6-2⅝	59⅜	118¾	1,374	1⅛
11	*Farragut*	Thornycroft.	3	E	240	5,600	...	4½	b	12-9	13-0	10-9	7-0¾	4-8	65.3	109.6	974	1
12	*Davis*	Thornycroft.	2	F	250	1,750	...	2	b	10-0	9-6	9-2	7-6	5-10½	44	88	854	1
13	*Fox*	Thornycroft.	2	F	250	1,750	...	2	b	10-0	9-6	9-2	7-6	5-10½	44	88	854	1
14	*Morris*	Mod. Normand.	2	C	250	1,750	...	...	b	8-9	9-4⅜	9-0	7-1	5-8	40	80	1,200	1
15	*Talbot*	Mod. Normand.	1	C	225	850	...	1.75	b	9-9	8-4½	8-1⅝	8-0	4-9½	38	38	1,275	1⅛
16	*Gwin*	Mod. Normand.	1	C	225	850	...	3.3	b	9-9	8-4½	8-1⅝	8-0	4-9½	38	38	1,275	1⅛
17	*Mackenzie*	Thornycroft.	2	F	250	850	...	2.94	b	6-9	7-2	7-6	4-10½	4-1½	20	40	538	1
18	*McKee*	Thornycroft	2	F	250	850	...	...	b	6-9	7-2	7-6	4-10½	4-1½	20	40	538	1
19	*Stringham*	Thornycroft.	4	E	240	7,200	...	3	b	10-9	12-10	10-10	7-0	4-6	63	252	1,480	1
20	*Goldsborough*	Thornycroft.	3	E	250	5,850	...	...	b	11-2	13-7	10-5	7-2½	5-0	72	216	1,396	1⅛
21	*Bailey*	Seabury.	4	M	245	5,600	...	...	b	11-6	10-6	12-0	9-0	6-3	56½	225	972	1
22	*Bagley*	Normand.	2	D	230	4,200	...	...	b	11-2	10-6	11-6	9-6	6-3	59⅜	118¾	1,552	1⅛
23	*Barney*	Normand.	2	D	230	4,200	...	...	b	11-2	10-6	11-6	9-6	6-3	59⅜	118¾	1,552	1⅛
24	*Biddle*	Normand.	2	D	230	4,200	...	6 84	b	11-2	10-6	11-6	9-6	6-3	59⅜	118¾	1,552	1⅛
25	*Blakely*	Normand.	3	D	250	3,000	...	...	b	8-10	10-5	10-0	7-8	6-6	50	150	1,244	1⅛
26	*DeLong*	Normand.	3	D	250	3,000	...	...	b	8-10	10-5	10-0	7-8	6-6	50	150	1,244	1⅛
27	*Nicholson*	Mosher.	3	G	250	3,500	...	...	b	8-8	10-11	8-9	7-0	7-6	52 5	157.5	1,340	1⅛
28	*O'Brien*	Mosher.	3	G	250	3,500	...	...	b	8-8	10-11	8-9	7-0	7-6	52.5	157.5	1,340	1⅛
29	*Shubrick*	Thornycroft.	3	F	250	3,000	...	...	b	8-4	10-8	10-3	6-9	6-9	45.67	137	776	1⅛
30	*Stockton*	Thornycroft.	3	F	250	3,000	...	...	b	8-4	10-8	10-3	6-9	6-9	45.67	137	776	1⅛
31	*Thornton*	Thornycroft.	3	F	250	3,000	...	...	b	8-4	10-8	10-3	6-9	6-9	45.67	137	776	1⅛
32	*Tingey*	Thornycroft.	3	F	250	3,000	...	...	b	8-4	10-8	10-3	6-9	6-9	45.67	137	776	1⅛
33	*Wilkes*	Seabury.	3	N	250	3,000	...	...	b	8-0	10-10	10-4	7-2½	6-4	45.67	137	1,370	1⅛
34	*Bainbridge*	Thornycroft.	4	E	300	8,000	...	...	b	11-2	15-6	10-4	7-0	11-6	80.5	315	1,346	1⅛
35	*Barry*	Thornycroft.	4	E	300	8,000	...	...	b	11-2	15-6	10-4	7-0	10-6	73.5	...	372	1⅛
36	*Chauncey*	Thornycroft.	4	E	300	8,000	...	...	b	11-2	15-6	10-4	7-0	11-6	80.5	315	1,346	1⅛
37	*Dale*	Thornycroft.	4	E	300	8,000	...	...	b	11-2	15-6	10-4	7-0	10-6	73.5	...	372	1⅛
38	*Decatur*	Thornycroft.	4	E	300	8,000	...	...	b	11-2	15-6	10-4	7-0	11-6	80 5	315	1,346	1⅛
39	*Hopkins*	Thornycroft.	4	E	300	8,000	...	...	b	11-2	15-6	10-4	7-0	10-6	73.5	...	372	1⅛
40	*Hull*	Thornycroft.	4	E	240	7,200	...	...	b	11-6	14-7	10-5	7-0	11-6	80.5	315	1,346	1⅛
41	*Lawrence*	Fore River.	4	P	250	8,400	...	...	b	10-8	15-0	12-3	8-0	10-6	73.5	...	372	1⅛
42	*Macdonough*	Fore River.	4	P	250	8,400	...	...	b	10-8	15-0	12-3	8-0	9-9	78	304	1,980	1⅛
43	*Paul Jones*	Thornycroft.	4	E	300	8,000	...	...	b	11-7	15-6	10-6	7-0	8-9	70	...	...	...
44	*Perry*	Thornycroft.	4	E	300	8,000	...	...	b	11-7	15-6	10-6	7-0	11-6	80.5	315	1,346	1⅛
45	*Preble*	Thornycroft.	4	E	300	8,000	...	...	b	11-7	15-6	10-6	7-0	10-6	73.5	...	372	1⅛
46	*Stewart*	Seabury.	4	N	300	8,000	...	...	b	11-0	16-4	11-0	8-0	10-4	80	315½	1,346	1⅛
47	*Truxtun*	Thornycroft.	4	E	230	8,300	...	...	b	11-9	15-2	10-6	7-0	8-5	67½	...	2,144	1⅛
48	*Whipple*	Thornycroft.	4	E	230	8,300	...	...	b	11-9	15-2	10-6	7-0	11-6	80.5	315	1,876	1⅛
49	*Worden*	Thornycroft.	4	E	230	8,300	...	...	b	11-9	15-2	10-6	7-0	10-6	73.5	...	372	1⅛

Destroyers.

Mosher — Seabury

S.	Tubes in one boiler.					Heating surface.				Drums.					Ratios.				
				Downtake.				H.S.	T.H.S.	Steam.		Water.							
	Number.	Diameter.	B.W.G.	Number.	Diameter.	Tubes in square feet.	All other heating surface in square feet.	One boiler.	All boilers.	Diameter.	Length.	Diameter.	Length.	Number.	H.S. / G.S.	T.H.S. / I.H.P.	I.H.P. / T.G.S.	Tubes. / Downtake.	Number.
	760	1¼	11	2	7½	2,37[illegible]	...	2,375	4,750	26½	131	14	129	2	62	2.96	20.88	6.48	1
	190	1¼	10	...	...	...	...	...	...	...	...	...	...	2	...	...	...	...	
	1,032	1¼	12	2	8	2,349	...	2,349	4,698	30	147	14	137	2	55.27	2.61	21.17	8.08	2
	170	1¼	10	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
	1,098	1¼	12	186	1½	2,630	...	2,630	5,260	2 22	131	14	117	2	55.36	2.63	21	6.89	3
	204	1¼	10	×	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
	1,098	1¼	12	186	1½	2,630	...	2,630	5,260	2 22	131	14	117	2	55.36	2.63	21	6.89	4
	204	1¼	10	×	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
	1,098	1¼	12	186	1½	2,630	...	2,630	5,260	2 22	131	14	117	2	55.36	2.63	21	6.89	5
	204	1¼	10	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
	1,445	1¼	15	2	9½	2,762.6	...	2,762 6	8,288	32	112	16	105½	2	51.6	2.59	19.92	7.5	6
	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
	1,445	1¼	15	2	9½	2,762.6	...	2,762.6	8,288	32	112	16	105½	2	51.6	2.59	19.92	7.5	7
	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
	1,098	1¼	12	186	1½	2,606	24	2,630	7,890	2 22	124	14	114	2	55	2.46	22.3	6.89	8
	204	1¼	10	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
	1,374	1 1/16	13	2	1.18	2,776	...	2,776	5,552	35.43	154	15.74	144	2	46.75	1.32	35.37	7.52	9
	178	1 1/16	11	2	10	...	...	...	...	...	...	...	...	...	...	...	...	...	
	1,374	1 1/16	13	2	1.18	2,776	...	2,776	5,552	35.43	154	15 74	144	2	46.75	1.32	35.37	7 52	10
	178	1 1/16	11	2	10	...	...	...	...	...	...	...	...	...	...	...	...	...	
	974	1¼	12	13	4	3,304	...	3,304	9,912	37	162	18	153	1	50.59	1.77	28.57	6.78	11
	546	1¼	...	...	...	...	...	...	...	...	...	7	...	2	...	...	...	...	
	854	1¼	13	2	8	2,381.5	...	2,381.5	4,763	30	148	16	134½	2	54.1	2.72	19.88	7.18	12
	170	1¼	11	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
	854	1¼	13	2	8	2,381.5	...	2,381.5	4,763	30	148	16	134½	2	54.1	2.72	19.88	7.18	13
	170	1¼	11	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
	1,200	1¼	15	2	9.57	2,002	...	2,002	4,004	32	114	16	105	2	50	2.30	21.8	6.31	14
	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
	1,275	1¼	15	2	9.57	1,870	...	1,870	1,870	32	124	16	118	2	49.2	2.20	22 37	6.71	15
	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
	1,275	1¼	15	2	9 57	1,870	...	1,870	1,870	32	124	16	118	2	49 2	2.20	22.37	6.71	16
	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
	538	1	...	2	6½	1,084	...	1,084	2,168	20	102½	10½	94½	2	54.2	2.55	21.2	5.34	17
	126	1¼	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
	538	1	13	2	6½	1,147	...	1,147	2,294	20	100	10½	94	2	57.3	2.69	21.2	5.34	18
	126	1¼	11	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
	1,480	1	12	12	4	4,005	...	4,005	16,020	31	142½	18	132	1	63.57	2 22	28.57	8.11	19
	368	1¼	11	...	...	...	...	...	...	...	...	7½	...	2	...	...	...	...	
	1,396	1¼	11	14	4	4,500	...	4,500	13,500	37	155½	18	137	1	62.5	2.30	27.08	8.07	20
	384	1¼	11	...	...	...	...	...	...	...	...	6½	...	2	...	...	...	...	
	972	1	12	4	5½	3,300	...	3,300	13,200	36	145½	18×23½	142	1	58.6	2 35	24.88	6 55	21
	300	1¼	11	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
	1,552	1 1/16	11	2	1.18	2,776	...	2,776	5,552	35.43	153	15.74	144	2	46 75	1.32	35.36	6.59	22
	...	...	...	2	10	...	...	...	...	...	...	...	...	...	...	...	...	...	
	1,552	1 1/16	11	2	1.18	2,776	...	2,776	5,552	35.43	153	15 74	144	2	46.75	1 32	35.36	6.59	23
	...	...	...	2	10	...	...	...	...	...	...	...	...	...	...	...	...	...	
	1,552	1 1/16	11	2	1.18	2,776	...	2,776	5,552	35 43	153	15.74	144	2	46 75	1.32	35.36	6.59	24
	...	...	...	2	10	...	...	...	...	...	...	...	...	...	...	...	...	...	
	1,244	1¼	11	2	8¼	2,525	...	2,525	7,575	32	129	16	122	2	50.5	2.52	20	6 66	25
	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
	1,244	1¼	11	2	8¼	2,525	...	2,525	7,575	32	129	16	122	2	50.5	2.52	20	6.66	26
	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
	1,340	1¼	11	164	1½	2,802	...	2,802	8,406	2 24	116	16	108	2	53 37	2.4	22.2	8.17	27
	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
	1,340	1¼	11	164	1½	2,802	...	2,802	8,406	2 24	116	16	108	2	53.37	2.4	22.2	8.17	28
	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
	776	1	11	2	7	2,516	...	2,516	7,548	30	118	16	112	2	55	2.51	21.9	7.65	29
	140	1	11	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
	776	1	11	2	7	2,51[illegible]	...	2,516	7,548	30	118	16	112	2	55	2.51	21.9	7.65	30
	140	1	11	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
	776	1	11	2	7	2,516	...	2,516	7,548	30	118	16	112	2	55	2.51	21.9	7.65	31
	140	1	11	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
	776	1	11	2	7	2,516	...	2,516	7,548	30	118	16	112	2	55	2.51	21.9	7.65	32
	140	1	11	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
	1,370	1	11	1	9	2,600	...	2,600	7,800	32	111	14½	108	3	56 93	2.6	21 9	13.25	33
	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
	1,346	1	11	14	4	4,455	...	[2]4,455	17,768	37	144	19	128	1	55.34	2.22	25.4	7.79	34
	372	1	11	...	...	4,403	...	[2]4,403	...	...	...	7½	126	2	59.91	...	...	...	
	1,346	1	11	14	4	4,455	...	[2]4,455	17,768	37	144	19	128	1	55.34	2 22	25.4	7.79	35
	372	1	11	...	...	4 403	...	[2]4,403	...	...	...	7½	126	2	59.91	...	...	...	
	1,346	1	11	14	4	4,455	...	[2]4,455	17,768	37	144	19	128	1	55.34	2 22	25.4	7.79	36
	372	1	11	...	...	4,403	...	[2]4,403	...	...	...	7½	126	2	59.91	...	...	...	
	1,346	1	11	14	4	4,455	...	[2]4,455	17,768	37	144	19	128	1	55.34	2.22	25.4	7.79	37
	372	1	11	...	...	4,403	...	[2]4,403	...	...	...	7½	126	2	59.91	...	...	...	
	1,346	1	11	14	4	4,455	...	[2]4,455	17,768	37	144	19	128	1	55.34	2.22	25.4	7 79	38
	372	1	11	...	...	4,403	...	[2]4,403	...	...	...	7½	126	2	59.91	...	...	...	
	1,346	1	11	14	4	4,403	...	4,403	17,612	37	145	19	129	1	59 91	2.44	24.49	7.79	39
	372	1	11	...	...	...	...	...	...	...	...	7½	...	2	...	...	...	...	
	1,346	1	11	14	4	4,403	...	4,403	17,612	37	145	19	129	1	59.91	2 44	24.49	7.79	40
	372	1	11	...	...	...	...	...	...	...	...	7½	...	2	...	...	...	...	
	1,980	1	11	1	6½	4,653[3]	...	4,653	18,117	42	126	18	115	3	59.65	2.15	27.63	36.69	41
	...	...	...	...	...	4,158[1]	...	4,158	...	...	...	...	...	...	59.4	...	...	...	
	1,980	1	11	1	6½	4,653[3]	...	4,653	18,117	42	126	18	115	3	59.65	2.15	27 63	36.69	42
	...	...	...	...	...	4,158[1]	...	4,158	...	...	...	...	...	...	59.4	...	...	...	
	1,346	1	11	14	4	4,458.22[2]	...	4 458 22	17,783	37	145	19	129	1	55.38	2.22	25.4	7.79	43
	372	1	11	...	...	4,408 22[1]	...	4,408.22	...	...	...	7½	126	2	59.98	...	...	...	
	1,346	1	11	14	4	4,458 22[2]	...	4,458.22	17,783	37	145	19	129	1	55.38	2.22	25.4	7.79	44
	372	1	11	...	...	4,408.22[1]	...	4,408.22	...	...	...	7½	126	2	59.98	...	...	...	
	1,346	1	11	14	4	4,458.22[2]	...	4,458.22	17,783	37	145	19	129	1	55.38	2.22	25.4	7.79	45
	372	1	11	...	...	4,408 22[1]	...	4,408.22	...	...	...	7½	126	2	59.98	...	...	...	
	2,144	1	11	1	11	4,655[3]	...	4,655	17,782	40	132	17½	132	3	56.21	2.22	25.37	13.88	46
	1,876	1	11	...	...	3,817[1]	...	3,817	...	...	...	...	...	...	56.71	...	...	13.14	
	1,346	1	11	14	4	4,455[3]	...	4,455	17,768	37	145	18½	132	1	55.34	2.22	25.4	7.79	47
	372	1	11	...	...	4,403[1]	...	4,403	...	...	...	7½	128	2	59.91	...	...	...	
	1,346	1	11	14	4	4,455[3]	...	4,455	17,768	37	145	18½	132	1	55.34	2.22	25.4	7.79	48
	372	1	11	...	...	4,403[1]	...	4,403	...	...	...	7½	128	2	59 91	...	...	...	
	1,346	1	11	14	4	4,455[3]	...	4,455	17,768	37	145	18½	132	1	55.34	2.22	25.4	7.79	49
	372	1	11	...	...	4,403[1]	...	4,403	...	...	...	7½	128	2	59.91	...	...	...	

SHIPS.

UNITED STATES.

The Secretary of the Navy, in his annual report, has made the following recommendations for the increase of the Navy:

"Three first-class battleships, two first-class armored cruisers, three gunboats, each of about 1,000 tons trial displacement; three gunboats, each of about 200 tons trial displacement, for insular service; three picket boats, each of about 650 tons trial displacement; three steel sailing training ships, each of about 2,000 tons trial displacement; one collier of about 15,000 tons trial displacement; four tugboats.

"The Department will submit to Congress in December next, as directed by the last naval appropriation bill, a general description of two sea-going battleships and two armored cruisers, according to which the battleships and cruisers above recommended should be built if appropriation is made therefor."

Cleveland.—This protected cruiser was launched on September 28th from the Bath Iron Works at Bath, Me. The *Cleveland* was authorized by an act of Congress approved March 3, 1899, and is a sister ship of the *Chattanooga*, *Denver*, *Des Moines*, *Galveston* and *Tacoma*, which were provided for by the same act. The length on water line is 292 feet; length over all, 308 feet 9 inches; beam molded, 41 feet 3¼ inches; beam extreme, 44 feet; free board forward, 20 feet; free board aft, 18 feet 6 inches; free board amidships, 15 feet 9 inches; mean draught in normal condition, 15 feet 9 inches; corresponding displacement, 3,200 tons. The speed required by contract is 16½ knots. She has a steel hull, sheathed and coppered. The engines are required to have an indicated horsepower of 4,700 and they will drive twin screws. There will be ten guns in the main battery. There are two 4-cylinder triple-expansion engines with cylinders 18 inches by 29 inches by 2 inches of 35½ inches by 30 inches stroke, which

will be furnished steam by six Babcock and Wilcox water-tube boilers constructed for a working pressure of 275 pounds to the square inch. The total grate surface will be 300 square feet, and the total heating surface about 13,000 square feet. There will be two funnels, the top of each being 70 feet above the grates. The coal capacity, with bunkers full, is 700 tons. This will give a radius of action at full speed of about 2,600 miles. At the most economical rate of steaming, probably about ten knots an hour, she will be able to travel about 9,800 miles without coaling.

The main battery will consist of ten 5-inch rapid-fire guns and the auxiliary battery of eight 6-pounder rapid-fire guns, two 1-pounder rapid-fire guns and four Colt machine guns. The sail area will be about 6,000 square feet. The guns will be designed for smokeless powder. Eight of the main-battery guns will be mounted on the main deck in recess ports, the four forward ones having a range from right forward to 60 degrees abaft the beam, and the four after ones from right aft to 60 degrees forward the beam. The two other 5-inch guns will be mounted behind shields on the spar deck, one forward and one aft. Four 6-pounders will be mounted on the main deck, and the Colt machine guns on the top of the hammock berthing. The magazines will furnish space for 250 rounds of ammunition for each of the 5-inch guns and 500 rounds for each of the 6-pounders.

Wilkes.—This torpedo boat was launched on Saturday, September 28.

Length on water line, 175 feet; width, 17 feet; displacement, 165 tons; speed, 26½ knots.

The boat is to be driven by twin-screws and two sets of triple-expansion engines of four cylinders each—one of 14, one of 22 and two of 25¼ inches diameter, the stroke being 18 inches. The horsepower is 3,000. The working steam pressure is 250 pounds, the boiler having 137 square feet of grate surface and 7,800 square feet of heating surface.

The Torpedo Boat Nicholson was launched from the Lewis Nixon Shipyard at Elizabethport, N. J., on September 23d. She is one of the largest boats of this class built by the Government. She is 185 feet long and 200 tons displacement, and her guaran-

teed speed is 26 knots. She is fitted with two triple-expansion engines, 18-inch high pressure, 27-inch intermediate pressure, and two low-pressure cylinders of 27½ inches and 18 inches stroke. She has three Mosher boilers, having total grate and heating surfaces respectively of 157.5 and 8,406 square feet. Her propellers are 6 feet 5 inches diameter, 9 feet 4 inches pitch, with a helicoidal area for one screw of 12.9 square feet.

Porpoise.—The *Porpoise* was launched from the same yard on the same date, and is the fourth of the six Holland submarine boats building in this yard. She is 64 feet 4 inches long, 11 feet 9 inches beam, and is equipped with a 160-horsepower gasoline engine for surface running, and a 70-horsepower electrical motor for submarine work. She is designed to make 10 and 8 knots respectively with these engines.

The New Coast Survey Steamer Bache was launched on September 20th from the yard of the Townsend & Downey Shipbuilding and Repair Co., on Shooter's Island. This steamer is 163 feet long, 27 feet beam and will draw 8 feet 2½ inches. She is fitted with triple-expansion engines, developing 175 horsepower, Scotch boilers, and is schooner rigged. The *Bache* will be especially equipped for survey work.

Chauncey.—This torpedo-boat destroyer was launched at noon, October 26, at the Neafie & Levy yards, Philadelphia.

She is designed for a trial displacement of 420 tons, with a L. W. L. length of 245 feet; beam, 23 feet 7¼ inches; mean draught, 6 feet 6 inches, and a trial speed of 28 knots.

The engines are two of the triple-expansion four-cylinder type, with cylinders 20½ inches by 32 inches by two of 38 inches by 22 inches stroke, and are designed for 8,000 horsepower.

The steam is supplied by four Thornycroft boilers, having a total grate surface of 315 square feet, and a total heating surface of 17,768 square feet.

The propellers are 7 feet 3 inches in diameter, 10 feet 10½ inches pitch, with a helicoidal area for each screw of 19.75 square feet.

Bainbridge.—This torpedo-boat destroyer, which is a sister ship to the *Chauncey*, had her builder's trials on October 19th

last. Four double runs were made over the measured mile with satisfactory results. The engines and boilers performed well, there being no trouble experienced either from heating of journals or priming of boilers. The coal used was not of the best, and there was considerable flaming at the two forward funnels.

Tuscarora.—This new revenue cutter was launched by the William R. Trigg Co., Richmond, Va., during the week ending November 2. The vessel is intended for service on the great lakes and is of the following dimensions: Length over all, 178 feet; length between perpendiculars, 162 feet; beam, molded, 30 feet; depth at side from base line amidships, 15 feet. The hull is of steel throughout and fitted with eight watertight athwartship bulkheads. The keel is of the flat type, composed of two thicknesses of plates, 14 pounds per square foot, and well riveted together. Above these inner and outer flat keels is a vertical keel of 15 pounds per square foot, reinforced with double angles. There are six intercostal longitudinals, three on each side of the vertical keel, standing square with the outside plating. The pilot house and chart room are located on the forecastle deck, just abaft the foremast. These houses are built of steel complete except the doors in the pilot house. The steering of the vessel is done by steam, the gear being so arranged that it can be operated by hand or steam from the pilot house, and steam from the top of the bridge. A screw hand gear is also fitted aft over the top of rudder head. The berthing space for the crew is on the berth deck forward and also under the forecastle deck. The petty officers, boatswain, carpenter and oiler have their staterooms and mess rooms directly aft of the crew's space on the berth deck. The wardroom officers are located on the berth deck aft of the machinery space. The wardroom mess room runs the whole length of the wardroom between the wardroom officers' staterooms. The captain's quarters are located directly aft of the wardroom, under the main deck. The main engine is of the vertical, inverted-cylinder, direct-acting, triple-expansion, surface-condensing type with cylinders of 17, 27 and 43 inches diameter and 24 inches stroke. Steam will be furnished by two single-ended boilers of the horizontal return fire-tube type, con-

structed for a working pressure of 160 pounds per square inch. Each boiler will have three Morison corrugated furnaces of 39 inches internal diameter. The total heating surface will be about 3,000 square feet; grate surface, 108 square feet. The boilers will be 11.8 feet outside diameter and 10 feet long over all. Independent feed pumps will be fitted in fire and engine rooms. The forced draft will be of the closed fire-room system; air being supplied by one blower. There will be one See hydropneumatic ash ejector. The contract price of the vessel was $157,000.

Revenue Cutters Nos. 9 and 10.—Bids were opened at the Treasury Department on October 12, 1901, for the construction of two small revenue cutters, to be known during the construction as *Nos. 9 and 10*, Revenue Cutter Service.

The following bids were received:

Name of bidder.	*No. 9.*	*No. 10.*	For both.
Racine Boat Manufacturing Co.	.....	$59,850	.....
Townsend & Downey	$79,612	91,637	.....
Spedden Shipbuilding Co.	39,600	53,100	$ 90,300
Wm. R. Trigg Co.	57,297	62,253	115,303

The contracts have been awarded to the Spedden Shipbuilding Co., at their combination bid of $90,300. *Cutter No. 9* is intended for harbor duty at Boston, Mass. *Cutter No. 10* will be stationed in St. Mary river for regulating the passage of vessels through the Sault Ste. Marie canal and river.

Revenue Cutter No. 9 is a small vessel of the tugboat class, and will practically be a duplicate of the *Hudson*, which made such a fine record in the engagement at Cardenas, during the Spanish war. Her principal dimensions will be as follows:

Length over all, feet and inches	98- 6
Breadth of beam, feet and inches	20- 6
Depth of hold, feet and inches	10- 3
Displacement at mean draught of 8 feet, tons	175

Revenue Cutter No. 10 will be of the same class, but somewhat larger. Her principal dimensions will be:

Length over all, feet	110–
Breadth of beam, molded, feet and inches	20– 6
Depth of hold, feet and inches	12– 0½
Displacement, tons	215

The machinery of the two boats will be constructed from the same plans. Each will have a Roberts water-tube boiler, with a grate surface of 72 square feet and a heating surface of 2,800 square feet. The engines will be of the ordinary vertical triple-expansion type, having cylinders 13⅛ inches, 21 inches and 32¼ inches in diameter respectively, with a stroke of 24 inches. The air pump and circulating pump will be independent of the main engine and of each other. Each vessel will be fitted with an evaporator. It is expected that the engines and auxiliaries will develop about 525 indicated horsepower at 160 revolutions of the main engine. The propeller of each vessel will be of manganese-bronze, having a diameter of 7 feet 6 inches, a pitch of 10 feet 6 inches and a helicoidal area of 20.5 square feet, divided between four blades.

AUSTRIA-HUNGARY.

Armored Cruiser E.—This new first-class armored cruiser is a vessel of 7,400 tons displacement, with a length of 383 feet 10 inches, a beam of 61 feet 8 inches, with a mean draught of 21 feet 4 inches. The engines are to develop 13,200 indicated horsepower to give a speed of 21 knots. She will have water-tube boilers of the Yarrow type, and her normal coal supply will be 750 tons. The armament will consist of two 24-centimeter (9.4-inch) 40-caliber guns in barbettes, one forward and one aft; ten 15-centimeter (5.9-inch) quick-fire 40-caliber Skoda guns in casemates, with twenty-seven smaller quick-fire and machine guns, with four torpedo discharges. Protection will be afforded by a partial armor water-line belt, extending between the two barbettes, of 9-inch hard steel, with 8-inch armored bulkheads at each end of belt, reaching up to and protecting the bases of the barbettes; a 2-inch armored deck; the armor for the heavy gun turrets being 8-inch, and for the casemates 5-inch. In her general design, the new cruiser resembles the *Kaiser Karl VI*, but

she is somewhat better protected, carries two more 5.9-inch guns, and will have a knot more speed.—"R. U. S. I."

Arpad.—This new second-class battleship is the second of the new division of battleships, of which the first, the *Hapsburg*, was launched ten months ago. It is expected that the third vessel of this type will be completed before the end of next year. All three have a displacement of 8,340 tons, or nearly 1,500 tons more than the *Kronprinz Rudolf*, which was previously the largest vessel of the fleet. They exceed the *Monarch* class, intended for coast defense, by 2,740 tons. Her dimensions are as follows: Length, 354 feet; beam, 65 feet 9 inches; displacement, 8,340 tons with an extreme draught of 23 feet. Protection is afforded by an armor belt of chrome-nickel-steel 8.8 inches thick, reaching from 4 feet 4 inches below to 3 feet 6 inches above the water line, and extending 63 per cent. of her length. Above the belt and reaching to the main or battery deck is a citadel protected by 4-inch armor, shut in by 8 inch athwartship bulkheads rising from the lower armor deck, which is 2.3 inches thick before the casemates, and 2.6 inches abaft. From the fore end of the armor belt to the ram the side is protected by 2-inch plating. A second armor deck 1.8 inches thick extends from the top of the belt, while the main deck between the fore and aft bulkheads is similarly protected, the combing of all the hatches being also armored. There are two barbettes for the heavy guns, one forward and one aft, protected by 8.4-inch armor, with ammunition tubes 7.2 inches thick; the secondary battery, of 6-inch quick-fire guns, will be mounted in double casemates, protected by 5.4-inch armor on the outer side and 3.3-inch on the inner side; the forward conning tower will be protected by 8-inch armor, decreasing to 6 inches on the communication tube; the after tower will have 4-inch armor, decreasing to 2 inches on the communication tube. All the armor will be of chrome-nickel-steel hardened by a special process.

The armament will consist of three 24-centimeter (9.4-inch) 40-caliber guns, two being carried in the fore barbette and one in the after; twelve 15-centimeter (5.9-inch) 40-caliber quick-firing guns, six each side, mounted in double casemates, one over the

other; ten 6-pounder and twelve 1-pounder quick-firing guns, with eight machine guns. The guns and ammunition hoists will be worked by either electricity or hand, while the ammunition tubes lead direct from the guns to the magazines, and it is calculated that by means of the electric hoists eight rounds a minute can be supplied. The axial height of the guns in the lower battery is 14 feet 8 inches above the water, in the upper battery 21 feet 4 inches, and that of the barbette guns 25 feet and 24 feet 4 inches fore and aft respectively. There will be two submerged torpedo discharges for 18-inch Whitehead torpedoes.

The ship will have twin screws, and the engines are to develop 11,900 indicated horsepower, which, with 136 revolutions, is to give a speed of 18.5 knots, steam being supplied by sixteen water-tube boilers on the Belleville system. The coal stowage will be for 840 tons. Electricity will be used for lighting the ship, working the guns, barbettes, ammunition hoists, ventilators, etc., the current being supplied by six dynamos, producing three-phase currents and under armor protection.—"R. U. S. I."

Szigetvár.—This new third-class cruiser, a sister ship to the *Zenta* and *Aspern*, is now nearly completed. She is 301 feet 10 inches long, with a beam of 39 feet 6 inches, a displacement of 2,350 tons and a draught of 14 feet 2 inches. Her armament will consist of eight 12-centimeter (4.7-inch) quick-firing Skoda 40-caliber guns, ten 6 pounder quick-firing guns, two machine guns and two submerged tubes for 18-inch torpedoes. The 4.7-inch guns are in sponsons, protected by 2-inch steel armor, the conning tower being similarly protected. The engines are to develop 8,000 indicated horsepower, to give a speed of 20.5 knots, steam being provided by Yarrow water-tube boilers. The coal supply is 250 tons, which, at 12 knots speed, will give a radius of action of 3,500 miles. She and her sisters are wood-sheathed.—"R. U. S. I."

FRANCE.

Leon Gambetta.—This armored cruiser was launched at Brest on October 26.

Her principal dimensions are as follows: Length, 486.75 feet; beam, 70.21 feet; draught, 26.9 feet; displacement, 12,600 tons.

The boilers are of the Niclausse water-tube type, twenty-eight in number, and supply steam for three vertical, inverted, triple-expansion engines driving three screws, and are expected to develop 27,500 indicated horsepower and to give a speed of 22 knots. The estimated radius of action at 10 knots is 12,000 miles.

Her armament will be four 7.63-inch, sixteen 6.48-inch, twenty-two 1.85-inch and two 1.45-inch guns, and five torpedo tubes, two of them submerged. The two large turrets, one forward and one aft, containing the four big guns, will have a protection of 7.87 inches thickness of armor; the six smaller turrets, containing twelve of the 6.48-inch guns, will have 5.5 inches protection, and the four in casemates, 4.7 inches.

The armor belt will run her entire length, and its greatest thickness will be 6.7 inches, the protection from deck to deck above it being 2.2 inches. The thickness of the lower armor deck will be 2.56 inches, and of the upper, 1.34 inches. Her complement will be 38 officers and 690 men. Her estimated cost is nearly $6,000,000, of which nearly $5,000,000 is for the ship, $1,000,000 for the guns and the torpedo tubes.

Montcalm.—Armored cruiser, delivered recently to the Navy by the Chantiers de la Seyne, had completed on September 27, the preliminary trials of the engines and boilers.

These trials took place on four different days, the first three occurring on August 24, September 4 and 18. During the course of these different trials the three engines have been pushed progressively to 6,000, 9,500, 14,000 and 18,200 indicated horsepower. On all the runs the engines and boilers acted very well. The last trial especially, at 18,200 indicated horsepower, was interesting from the fact that not one unfavorable observation was made. During this last trial a speed of 20.85 knots was made over the official trial course.

As the bottom of the ship had not been cleaned before these trials, it may be expected that this speed will certainly be exceeded on a full-power trial with a clean bottom. The vibrations of the vessel at this last high speed were noticeably insignificant.

During the trials the *Montcalm* proved herself to possess re-

markable powers of evolution. At high speeds the steering gear gave the greatest satisfaction.

If these results are confirmed on the official trials, as it cannot be doubted they will, the *Montcalm* will prove a valuable recruit to the French fleet. She will also be the first of her type to enter into regular service. The others of this same type are the *Gueydon* and the *Dupetit-Thouars*.

Iéna.—This new first-class battleship has concluded her trials at Brest satisfactorily. During a six hours' run with the engines developing 9,000 indicated horsepower, a mean speed of 16 knots was maintained; all the twenty boilers were used, and there was a consumption of coal of 20.45 pounds for each square foot of grate surface. At the two hours' full-speed trial the engines developed 16,500 indicated horsepower, 1,000 horsepower over the contract, making 125 revolutions and giving a speed of 18.2 knots, with a coal consumption of 27.6 pounds per square foot of grate surface, and 1.72 pounds per indicated horsepower per hour.—"R. U. S. I."

Jeanne d'Arc.—This new first-class armored cruiser has commenced her trials off Toulon, but the results have not been satisfactory. The ship is intended to go 23 knots, with 1,400 tons of coal, her normal supply, in her bunkers; but up to the present, although carrying less coal, a speed of 18 knots only has been reached, as the bearings have become hot when the engines have been run up to 110 revolutions, although at full speed they are supposed to make 120 revolutions; moreover, serious defects have developed in the feeding of the boilers, which are of the small-tube Guyot type, and the temperature of the stokeholds is so high that they are quite unbearable. On a recent trial, with twenty-four boilers alight out of thirty, fires had to be drawn in no less than twenty; and with only four boilers working the ship had to crawl back to Toulon at 3 knots. A special inquiry is to be held, and it is even stated that her boilers may have to be removed and others of a different type substituted. —"R. U. S. I."

Chateaurenault.—This new first-class cruiser has also been continuing her trials; during an hour and a half's run under

forced draft the engines developed 23,200 indicated horse-power, making 129 revolutions and giving a speed of 23.3 knots with the wind and 24.2 knots against. As in the *Jeanne d'Arc*, however, the heat in the stokeholds is so great that they are pratically uninhabitable when all the fires are alight, and the authorities at present seem unable to devise any satisfactory arrangement for remedying this grave state of things, while hot bearings have also given a great deal of trouble, and it is now proposed to substitute steel for bronze, a change which will take from four to five months to effect.—" R. U. S. I."

Siroco.—The new sea-going torpedo boat *Siroco*, has completed her trials at Cherbourg ; at full speed, with engines making 355 revolutions, she maintained a speed of 28.3, which is more than 2 knots over the contract; with one boiler she attained a speed of 20 knots during a three hours' trial. A sister ship, the *Mistral*, maintained a speed of 28.1 during her full-speed trial, which is also a trifle over 2 knots above the contract speed, and with one boiler only can steam 20 knots. Although not so powerfully armed as the English destroyers, they are really more trustworthy vessels at sea, as they are much more strongly built. Another vessel of the same type, the *Simoun*, built at Havre by the Forges et Chantiers de la Méditerranée, has made 26 knots at her preliminary trials; while a fourth, the *Trombe*, at Lorient, has maintained a speed of 26.6 knots, being .6 over the contract. A fifth of the class, the *Tramontaine*, has commenced her trials at Rochefort. At a three hours' trial, the engines, making 290 revolutions, gave a speed of 23 knots, and during an hour's run at full speed, with the engines making 290 revolutions, gave a speed of 23 knots, and during an hour's run at full speed, with the engines making 339 revolutions, a maximum speed of 29.8 knots was attained. These so-called torpilleurs-de-haute-mer are really small torpedo-boat destroyers, and have their engines and boilers protected by 1-inch armor of hard steel, with transverse bulkheads fore and aft of the same thickness. They are said to be much stronger built than the new 300-ton destroyers of the *Durandal* type.

G 14.—Official instructions have been received at Brest for

the construction in 1902 of armored cruiser *G 14*, which will take later the name of *Thiers* or *Lamartine*. Her length will be 479 feet; beam, 70.2 feet; displacement, 12,550 tons, and she will have three sets of engines, which are to develop 27,500 indicated horsepower; speed, 22 knots. She will carry four 7.64-inch guns in two turrets, one forward and one aft; sixteen 6.4-inch guns, twelve in pairs in turrets and four in casemates; twenty-two 1.85-inch guns and five torpedo tubes, two submerged. Her water-line armor belt will be 6.7 inches in thickness, and above will be a thinner belt of 2.2-inch armor extending to the upper deck. She will have two armor decks, the lower of which will be 2.56 inches in thickness. Her complement will be 38 officers and 690 men, and her cost about $5,500,000.

Sirène.—The latest trials of the *Sirène* have given some remarkable results when the nature of the vessel and the novelty of the type are considered. In a 24-hours endurance trial, she developed a speed of 7.5 knots an hour for three hours on the surface; then steamed for three hours submerged; then coming to the surface and continuing her run at 7.5 knots an hour for seventeen hours, and finally a submerged run of an hour during which she fired two torpedoes.

The *Sirène* has a radius of action of 500 miles at 7 knots, which is very good.

The great improvement over the *Narval* consists in the ability to make the dive without any considerable delay, the time of preparation having been reduced from twenty minutes to nine minutes from the time the order is given to extinguish the fires.

The *Silure*, the *Espadon* and the *Triton* are of the same type, and will possess the same advantages as the *Sirène*.—"Le Yacht."

Triton.—The new French submarine *Triton* is the sixth of those completed since the beginning of the year, and the third of those finished at Cherbourg during that time. The craft is a perfected *Narval*. The displacement is 106 tons; length, 111½ feet; beam, 13¾ feet. As in the *Narval*, there are two sets of motors—steam for use above and electricity when submerged. The steam engines develop 217 horsepower, and the speed is about 12 knots. The complement is 2 officers and 9 men. Four

torpedo tubes will be carried, and the cost is about £25,000.—"Engineers' Gazette."

This submarine boat was tried recently in free route on the surface, and a speed of 10 knots per hour for four hours was maintained. The vessel and her machinery gave perfect satisfaction.

Espadon.—The French submersible torpedo boat *Espadon* was launched recently at Cherbourg. This is the third of the series of boats which are an improvement on the *Narval*, and are able to sink in about one-third of the time required by that vessel. This vessel has been given her first underwater trial. It lasted for four hours and was satisfactory, her crew not suffering any discomfort.

Trombe.—This sea-going torpedo boat, having terminated completely her trial and subsequent inspections of machinery, has been ordered to Brest, where she will be placed in reserve and will form a group with *L'Audacieux*, of the same type. *La Trombe* has given complete satisfaction in all her trials, and her construction is so solid that upon striking upon the rocks of Groix while running at great speed, the only damage sustained was the crumpling up of the hull plates extending aft for some feet. These plates have since been replaced.

Throughout the remainder of the vessel, from the conning tower aft, nothing was injured by this severe shock. No derangement whatever was caused in either the boilers or the engines. Such a result does honor to our constructors, and is it not better in this type of vessel to demand a few knots less speed and more strength? If the results of the accidents to *La Trombe* and the *Cobra* are compared, it is easily seen that the advantage in strength is on the side of the French vessel.—"Le Yacht."

Protected Twin-Screw Torpedo Boats Siroco and Mistral.—MM. Augustin Normand & Co., of Havre, have recently delivered to the French Government, at Cherbourg, two protected torpedo boats, fitted with the same machinery and boilers as the *Cyclone*. The trials offer special interest on account of the very heavy weights carried. The dimensions are:

Length on load line, feet and inches	147- 0
Extreme breadths outside armor, feet and inches	16-10

The nickel-steel armor extends to the machinery and boiler compartments, and is distributed as follows:

24 millimeters (1 in.) bare.	Vertical sides from 8 inches below the water line to the deck.
	Fore-and-aft bulkheads from 16 inches below the water line to the deck.
	Vertical sides of coverings of all parts of machinery and boilers, and of the steering engine above deck.
9 Millimeters ($\frac{1}{2}\frac{1}{2}$ in.) bare.	All horizontal parts of deck and hatchways.

The total extra weight resulting from the addition of armor—including the strengthing of the hull amidships and the addition of a central hollow keel 1 foot high, extending to about one-half the length of the boats, and intended to stiffen the central part of the structure and to check rolling—is not less than 24 English tons.

The hulls are very strong, as was proved by an accident which occurred to an exactly similar protected torpedo boat (*Trombe*) in a trial outside Lorient. When steaming at about 23 knots, during foggy weather, she ran end-on against a rock rising above water; and, although several men were injured by the shock, no material damage, beyond the crushing of about 25 feet of the fore part, occurred to the boat, which was towed back to harbor.

The total other weights carried on trial, exclusive of chains, anchors, masts, boats, etc., and comprising only torpedo tubes and compressing pump, artillery and ammunition, provision, water for boilers and crew, coals necessary for steaming 1,020 nautical miles at 14 knots, crew and effects, provisions, including 5 tons for sundries to complete displacement at sea, amounted to 39.9 English tons in the *Siroco* and 43.2 tons in the *Mistral*. Accordingly, the displacement on trial, 177.5 English tons for the *Siroco* and 178.7 tons for the *Mistral*, was that of the boats on service.

It has very wisely been the general custom of the French Admiralty to have the trials of ships made at what was believed to be full load; but lately this rule has been enhanced, as it was ascertained that these full-load trial displacements were often inferior to the real displacement on service.

If the 24 tons due to armor are added to the above weights, we see that the total weights carried on trial amount to 63.9 and 67.2 tons respectively; that is to say, to about 37 per cent. of the total displacement. This is far from the 35 tons carried on board destroyers of much larger displacement. The weight of coals put on board was determined by an eight hours' preliminary trial.

The full-speed trials, which took place after the ordinary preliminary runs on the measured mile, were of four hours' duration, one hour of which was to be run at 22 knots, one hour at maximum speed, and the next two hours at 22 knots.

The one-hour maximum speed was found to be 28.341 knots for the *Siroco* and 28.102 knots for the *Mistral*. Only 26 knots were due according to contract. The maximum speed of the *Cyclone* (unprotected), with a displacement of 141 English tons, was 30.7 knots.

It is generally admitted that great speed can only be attained by reducing all weights to, and even beyond, their extreme limits. This is, no doubt, true to a great extent. However, from the above results, which may be said to be extraordinary on account of the unusual importance of the deadweight carried, there seems good reason to believe that not only sufficient strength but a very complete armament, and even some protection, may be given to torpedo boats and destroyers without an abnormal reduction of speed.—"Engineering."

GERMANY.

Schwaben.—A battleship of the *Wittelsbach* class, was launched at Wilhelmshaven on the 9th of August, after having been on the stocks only ten months. Her dimensions are:

Length between perpendiculars, feet	393.7
over all, feet	413.4
Breadth, extreme, feet	68.24
Draught, mean, feet	24.93
Displacement, tons	11,800
I.H.P	15,000
Speed, knots	19
Coal, normal, tons	650
bunker capacity, tons	1,000

The armor covers an area of 12,917 square feet, and weighs 2,400 metric tons.

There are three triple-expansion engines, with cylinders 38.6, 54.3 and 85.8 inches diameter and a stroke of 37.4 inches, designed to develop 15,000 indicated horsepower when making 115 revolutions per minute, and to give the ship a speed of 19 knots. The screws are 15.75 feet diameter.

Steam is supplied by six fire-tube and six water-tube boilers of the Thornycroft-Schultz type, with a total heating surface of 41,873 square feet.

Torpedo Boat G. 108.—On September 7, the new German *Torpedo Boat G. 108*, was launched from the Germania shipbuilding yard. This is the first of the new type of torpedo boat which is being built in the Kiel yards. Five sister boats are now being built at Kiel, and they will be launched during the next few months. Thus the Germania yard will have constructed six torpedo boats, *G. 108* to *G. 113* inclusive, according to its own designs. These craft will be as large as the division boats, and their twin engines will develop nearly 6,000 horsepower.

GREAT BRITAIN.

King Alfred.—The armored cruiser *King Alfred*, one of four vessels building for the Navy, was launched on October 28th from the Naval Construction Works of Messrs. Vickers, Sons & Maxim, Limited. The four new ships resemble the *Powerful* and *Terrible*, the apparent differences being that they have no military tops on their masts, and the poop has been cut away to increase the weight available for armor and guns; but great changes have been otherwise made, and the vessels of the *King Alfred* type are practically without equals. The speed has been increased to 23 knots. There are four more 6-inch quick-firing guns, but as each individual gun is of greater power, and attains a higher rate of fire, the weight of projectiles which may be discharged per minute has been increased from about 6½ tons in the *Powerful* to about 9 tons in the *King Alfred*, while the muzzle energy has been more than doubled. The *Powerful* was a protective-deck cruiser, with 6-inch casemates for her 6-inch quick-

firing guns, and similar protection for the bow and stern 9.2-inch guns.

In the *King Alfred* the armor protection is most effective. The main and auxiliary machinery and boilers and the magazines are protected by a water-line belt 11 feet 6 inches deep, extending over half the vessel's length, and varying in thickness from 6 inches amidships to 4 inches at the ends. At the after end of this belt a 5-inch armored bulkhead is fitted, and 2-inch nickel-steel protective plating is fitted on the bows. Abaft the screen bulkhead is a protective deck 2½ inches thick, affording protection to the steering gear and after capstan, &c. Within the citadel two protective decks are worked, the upper being 1½ inches thick and the lower 1 inch thick. The 9.2-inch guns are protected by 6-inch barbettes, in addition to gun shields. The 6-inch guns are each enclosed in a separate casemate, these being formed of 5-inch hard-faced armor. The conning tower is of 12-inch armor, with an armored tube 7 inches thick, affording protection to the controlling gear, &c.

The main armament includes two 9.2-inch Vickers' guns, the perfection of the mechanism and mounting of which enables a rate of fire of four aimed rounds per minute with 380-pound shot, developing a muzzle energy of 17,830 foot-tons. Besides the two 9.2-inch guns mounted as bow and stern chasers, the *King Alfred* has twelve 6-inch guns, which are mounted in a series of two-story casemates, four on either broadside, and these 6-inch guns have on trial fired eight aimed rounds per minute, the projectile being of 100 pounds weight. Four of the 6-inch guns, as well as one of the 9 2 inch weapons and two 12 pounders, fire ahead in line with the keel, while the same number of guns can discharge astern, the total number of projectiles being thus one hundred and sixteen, with an aggregate weight of 5,720 pounds per minute ahead or astern; while the broadside fire totals 11,190 pounds, a weight of shot which is not equalled by any other type of cruiser thus far conceived. There is also a large number of 12-pounder and machine guns.

The *King Alfred* is to maintain a speed of 23 knots. The propelling machinery consists of two sets of four-cylinder triple-

expansion engines. Each of the two sets is designed to develop 15,000 indicated horsepower, giving a combined indicated horsepower of 30,000. Steam is supplied by water-tube boilers of the latest Belleville economizer type, working at a pressure of 300 pounds per square inch. Each set of engines is placed in a separate engine room, divided by a longitudinal watertight bulkhead which extends the whole length of the engine room. Each engine room is in all respects similar to, but entirely independent of, the other. The main engines are of the inverted type, supported on cast-iron columns at the back and inclined wrought-steel columns at the front. The sole plates, or main-bearing frames, are of cast steel, strongly bolted together so as to form a stiff foundation for the engines. All the cylinders are fitted with separate liners and are steam jacketed. The diameter of the high-pressure cylinder is 43½ inches, that of the intermediate cylinders 71 inches, and that of the two low-pressure cylinders 81½ inches, all having a stroke of 48 inches. The high-pressure cylinder is fitted with one piston valve of the inside type, the intermediate cylinder is fitted with two piston valves having adjustable packing rings, whilst the two low-pressure cylinders are fitted with double-ported flat-slide valves, having a special type of relief ring.

There are two air pumps on each engine worked by levers in the usual manner from the main engines. The main condensers are four in number, of cast gun-metal, having a collective cooling surface of 32,000 square feet. There are two condensers to each set of engines, one forward and one aft, bolted to the back columns and resting on a seat. At the after end of each engine room is placed an auxiliary condenser, having a cooling surface of 1830 square feet. Under each auxiliary condenser is placed a combined air and circulating pump. Water is circulated through the main condensers by four 24½-inch centrifugal circulating pumps, each driven by independent engines, having, in addition to the suctions from the sea, the usual bilge connections.

The boilers are placed in four separate compartments, there being in all eight stokeholds running athwartships. The forward group in each boiler room consists of a single row of

boilers, and the after group in each are placed back to back. There are thus 43 boilers with economizers, viz: Five boilers having 10 elements, with 8 element economizers; 28 boilers having 9 elements, with 7 element economizers; and 10 boilers having 8 elements, with 6 element economizers.

The other auxiliary machinery in the engine rooms comprises four electric-light engines and dynamos, two steering engines, two reversing engines, two turning engines, two hot-well pumps, four fire and bilge pumps, one drain-tank pump, one latrine pump, four feed and brine pumps, two circulating and fresh-water pumps, four sets of evaporators, two distilling condensers, two ventilating fans and engines. In the boiler rooms are eight Weir's feed pumps, six air-blowing engines for supplying the furnaces with small jets of air under a pressure of 15 pounds per square inch, sixteen forced-draft fans, with open double-acting steam engines, and eight double-cylinder ash-hoist engines. In the outside machinery space are two coal-hoisting engines, two air-compressing engines and pumps, and four air reservoirs with valves complete; one ice-making machine, one workshop engine and one hydraulic-pumping engine.

The length of the *King Alfred* is 500 feet; width, 71 feet, and when in fighting trim she will displace 14,100 tons, the draught then being 26 feet. The vessel carries 2,500 tons of fuel in her bunkers, and will, therefore, be able to steam at a cruising speed of 14 knots for 12,500 sea miles, equal to a voyage from Portsmouth to Melbourne, without renewing her fuel supply. According to the navy estimates she will have cost, when ready for sea, £1,011,759. Her complement of officers and men will be 900.—"Engineering."

Hogue.—This cruiser had her preliminary steam trial on September 12, the results being satisfactory. While the coal and water consumption were regarded as excessive, the engines worked splendidly and maintained with ease a speed of 16.5 knots an hour. Electricity is extensively used on this vessel for auxiliary purposes. In addition to being used for lighting purposes and for use with the guns and torpedo armament, it will also be used for working the capstan and steering engines, the venti-

lating fans, winches and cranes. If its use for these purposes is found satisfactory it will be adopted for all new vessels.—"Naval and Military Record," September 19.

Bedford.—A first-class cruiser of 9,800 tons and 22,000 indicated horsepower. She belongs to what is now known as the County class, of which five were ordered by the Admiralty from Clyde firms. The *Bedford* is the first of the lot to be ready, well within contract time. Her dimensions are:

Length between perpendiculars, feet	440
Breadth, molded, feet and inches	66–2
Normal draught, feet and inches	24–6
Displacement at load draught, tons	9,800
Normal freeboard amidships, feet	19
Engine power, indicated horsepower	22,000
Boiler pressure, pounds	300
Speed, knots	23
Normal coal capacity, tons	800

The *Bedford* has side protection extending over a length of about 350 feet from the stem to the armor bulkhead, which is 3 inches thick. The side armor is of specially hardened steel, of three thicknesses—4½ inch, 3-inch, and 2-inch—the 4½-inch armor extending from the armor bulkhead forward for a distance of about 240 feet, the 3-inch armor for a distance of about 40 feet, and between this and the stem there is 2-inch nickel-steel armor. The protective deck proper extends from stem to stern, and ranges in thickness from ¾-inch within the range of side armor to 2-inch thickness outside. Another deck, 1¼ inches to 1 inch in thickness, forms a crown over the side armor and armor bulkhead, etc. The coal bunkers range along the sides of the machinery compartments both below and above the lower deck, and are provided with fittings for the rapid handling of the coal. The vessel's normal coal capacity is about 800 tons, but this can be doubled if necessary, ample space being allotted for this essential requirement.

The *Bedford* has two sets of triple-expansion engines fitted in two water-tight compartments, each set having four inverted cylinders working on four cranks. Each high-pressure cylinder is 37 inches diameter, each intermediate 60 inches, and each of

the low-pressure cylinders 69 inches, and a stroke of 3 feet 6 inches. The high-pressure and intermediate-pressure cylinders are each fitted with a piston valve, and each low-pressure cylinder with a double-ported slide valve with a relieving ring at the back. All the valves are worked by Stephenson link gear. The reversing is effected by means of double-cylinder steam engines, with gear of the all-round type, hand gear also being fitted. The crank, thrust, and propeller shaftings are of forged steel and hollow. Each of the propellers has a boss of gun metal fitted with three adjustable blades of manganese-bronze. The main condensers are placed at the back of the engines, and are of cast brass of oval form fitted with brass tubes, the condensing water being supplied by four centrifugal pumps of gun metal, each fitted with an independent engine. The feed, bilge, and hot-well engines are all independent and separate from the main engines, steam for these and all the other auxiliary machinery being supplied by a special line of steam pipes. The auxiliary exhaust steam is arranged to discharge to the auxiliary condensers, the atmosphere and the low-pressure receivers. There are two auxiliary condensers, each fitted with a circulating pump and a small air pump. The vessel will have a complete distilling plant to supply fresh water to the boilers and for drinking purposes, four sets of engines and dynamos for producing the necessary current for electric lighting, two double-cylinder direct-acting engines with the necessary gear for steering purposes, two complete sets of air-compressing engines and pumps, with the necessary air reservoirs and columns for charging torpedoes, and one ice-making machine of the cold-air type, including an ice-forming chamber and a pump for circulating water in the air cooler.

For steam generation there is an installation of thirty-one water-tube boilers and economizers, all of the latest Belleville type. The boilers are arranged in three groups, each group fitted in a watertight compartment, and they are designed to work at a pressure of 300 pounds. Air-pumping engines in each boiler room supply air to the furnaces and combustion chambers, while the necessary air for the stokehold ventilation is sup-

plied by large fans. Fans are fitted for the engine room and ship ventilation. An electric installation is arranged throughout the vessel on the double-wired system, whilst six powerful search-lights are fitted, two on the forward bridge, two on the shelter deck aft and one on each mast on a platform of great elevation. The vessel will have three funnels and two masts. Her complement is about 700 officers and men.—"Marine Review."

Essex.—Another of the County class has been launched from the government dock yard at Pembroke, but the machinery for this cruiser has been built at the Clydebank Works, Glasgow. It consists of two sets of main engines of the four-cylinder triple-expansion type, each of the two sets designed to develop 11,000 indicated horsepower, giving a combined indicated power of 22,000. Steam is supplied by water-tube boilers of the Belleville type. The safety valves on the boilers are loaded to a pressure of 300 pounds per square inch. The diameters of the high and intermediate-pressure cylinders are 37 inches and 60 inches respectively, while the diameter of each of the low-pressure cylinders is 69 inches, all having a stroke of 42 inches. The high and intermediate-pressure cylinders are fitted with piston valves of the inside type, having approved adjustable packing rings, while the low-pressure cylinders are fitted with treble-ported flat-slide valves on their sides, having a special type of relief frame to relieve them of steam pressure, and the weight of all the valves is suitably balanced in order to reduce the strain on the valve gear as far as possible.

The cylinders, which are entirely independent castings, are bolted together to provide sufficient longitudinal stiffeners, and to further increase their stability in the event of ramming, etc., strong struts are fitted between the high-pressure cylinder and the forward structure of the vessel, as well as transversely between the respective cylinders in each engine room. The barrels of the high-pressure and intermediate-pressure cylinders are made of forged steel, and those for the low-pressure cylinders of special close-grained cast iron, and are steam jacketed. The valve gear is of Stephenson link-motion type, and is actuated by means of a double-cylinder engine attached to one of the interme-

diate front columns at the level of the starting platform and beside the starting handles. Each of the reversing levers is provided with screw gear, so that the valves of each cylinder may be linked up independently. The pistons, cylinder covers, and steam-chest doors are of cast steel, the piston and connecting rods are of Siemens-Martin steel, and metallic packing has been employed for all stuffing-box glands of the piston rods and valve spindles of the main engines, as well as for all of the auxiliary engines throughout the vessel. The crank shafts are hollow, and each consists of two interchangeable pieces 18 inches in diameter at the journals. The crank arms are cut away as much as possible for lightness and for convenience in fitting the centrifugal lubricators. The thrust shaft and propeller shafting are also hollow, the shafting being 17 inches diameter inboard and 19½ inches diameter outside the ship. The propellers are three-bladed, working inwards, and are 16 feet 3 inches in diameter; the bosses are of gun metal and the blades are of manganese-bronze. The blades are secured to the bosses by large forged naval-bronze pins. Tail pieces and guards for preventing eddies either forward or aft of the propeller have been fitted in accordance with the usual Admiralty practice.

The four main condensers are of cast brass, having a total cooling surface of 23,000 square feet. The steam is condensed outside the tubes, which are ⅝ inch in external diameter by .048 inch thick, the circulating water passing through them. The water is supplied by four large Allen's circulating pumps, each driven by an independent engine. The pumps with steam of 200 pounds pressure, are each capable of discharging per hour 1,200 tons of water from the bilge. The engines driving them may exhaust into the atmosphere and work at a speed of 300 revolutions per minute. The exhaust steam from the whole of the auxiliary machinery in the ship is led into the auxiliary exhaust pipes, which are connected with the atmosphere by the auxiliary exhaust pipe carried up the funnel, and also with the low-pressure receivers and the respective auxiliary condensers in either engine room. Each of these condensers has its own air and auxiliary circulating pumps entirely independent of those

for the main condenser, and are driven by independent engines. The combined cooling surface of these two auxiliary condensers is 3,150 square feet, and their tube casings are of rolled brass sheets.

For the *Essex* are provided in all thirty-one Belleville boilers of the economizer type—eight boilers for the forward room, eleven for the second and twelve for the after boiler room. The number of elements in the boilers vary, but each element consists of seven pairs of tubes screwed in the usual junction boxes of malleable cast iron. These tubes, $4\frac{1}{2}$ inches in external diameter, are of cold solid-drawn steel, but in the economizer elements there are eight pairs of tubes, and these are $2\frac{3}{4}$ inches in diameter. The total heating surface of the boilers is 33,100 square feet, and in the economizers 17,200 square feet, or in all 50,300 square feet. The grate area is 1,610 square feet, giving a ratio of 31 square feet of heating surface to one of grate area, while the heating surface per unit of power to be developed is 2.29 square feet. The main feed-pump system consists of three double-acting pumps of the Weir type, one in each boiler room. These pumps draw by independent pipes from the feed tanks and deliver by branch pipes to the feed regulators attached to the boilers. The three pumps of the auxiliary-feed system are placed one in each compartment. These auxiliary pumps are also connected to the main-feed tanks, and, in addition, have separate connections to the reserve fresh-water tanks, and each discharges to the feed regulators in connection with the boilers. The main steam supply is conveyed by four lines of steel steam pipes, two lines being arranged on each side of the ship, each line entirely independent of the other, as are also the connecting pipes from the boilers to each of the lines. Any boiler may, therefore, be cut off from the system without interfering with the performance of the others in the compartment, as may also any compartment from which one of these main steam pipes lead, without affecting the efficiency of the other compartment. Any group of boilers may supply steam to any of the engines.

The armament of the *Bedford* consists of two twin 6-inch guns in barbettes—one forward and one aft—enclosed in gun house,

with specially-armored inclined shields. These guns are served through armored trunks from the magazines and shell rooms. The barbette walls are 4 inches thick, and are well supported to the general structure. Four 6-inch guns in casemates on the upper deck, and four 6-inch guns in casemates on the main deck forward and aft, together with the twin guns, give fore-and-aft fire at a high range. Two 6-inch guns in midship casemates on main deck secure a heavy broadside fire. The fronts of the casemates are 4-inch thick hard steel, with the rear plates 2 inches in thickness. Eight 12-pounder 12-cwt. guns and two 12-pounder 8-cwt. field and boat guns are placed at suitable positions, and there is an auxiliary armament of three 3-pounder and eight Maxim guns. At the fore end of the vessel is a steel conning tower of 10 inches thickness, with a communicating tube to protect the gear for controlling operations throughout the ship.

The dimensions of the *Essex* are similar to those of the *Bedford*. Both vessels will have a speed of 23 knots, and yet with such great speed both are armored heavily enough to face anything but the heaviest of battleships.—"Marine Review."

Vengeance.—New first-class battleship, has satisfactorily concluded her trials. At her thirty hours' trial at one-fifth her power, she drew 26 feet fore and aft, and had 254 pounds of steam in her boilers. The vacuum was 26.8 inches starboard, and 26.9 inches port, and the revolutions were 66.11 starboard, and 65.88 port. The collective indicated horsepower was 2,885, which gave the ship a speed of 11.35 knots. The coal consumption was 1.69 pounds per unit of power per hour. At her four-fifths trial the coal consumption was 1.51 pounds, and the speed of ship 17.5 knots, the engines developing 10,387 indicated horsepower and making 102 revolutions. At her full-speed trial the ship drew 26 feet on an even keel, and had 298 pounds of steam in her boilers. The vacuum was 26 inches, and the revolutions were 110.8 starboard, and 110.5 port. The total indicated horsepower was 13,852, which gave the ship a speed of 18½ knots. The coal consumption was 1.72 pounds per unit of power per hour. —"R. U. S. I."

Espiegle.—A new sloop built at Sheerness Dockyard, has

completed her official steam trials, the results being as follows: Thirty hours' trial at three-fourteenths full horsepower—pressure of steam in boilers, 204.9 pounds; pressure of steam at engines, 202.2 pounds; vacuum—starboard, 26.48 inches; port, 26.04 inches; revolutions—starboard, 124.8; port, 126.3; indicated horsepower—starboard, 175.7; port, 162; total indicated horsepower, 337.7; speed, 10 knots; coal consumption, 1.53 pounds per indicated horsepower per hour. Trial at five-sevenths full horsepower—pressure of steam in boilers, 211.6 pounds; pressure of steam at engines, 197.4 pounds; vacuum—starboard, 26.4 inches; port, 26.4 inches; revolutions—starboard, 178.7; port, 179.3; indicated horsepower—starboard, 515.7; port, 515.2; total indicated horsepower, 1,030.9; speed, 13.5 knots; coal consumption, 1.55 pounds per indicated horsepower per hour. Eight hours' full-power trial—pressure of steam in boilers, 213.1 pounds; pressure of steam at engines, 198.9 pounds; vacuum—starboard, 26.72 inches; port, 26.84 inches; revolutions—starboard, 197.6; port, 200.6; indicated horsepower—starboard, 720.2; port, 704.8; total indicated horsepower, 1,425; speed, 13.5 knots; coal consumption, 1.69 pounds per indicated horsepower per hour. The whole of the trials were successful, the indicated horsepower at the full-power trial being 25 in excess of the power stipulated in the contract. The *Espiegle* is fitted with the Babcock and Wilcox water-tube boilers.—" R. U. S. I."

Victoria and Albert.—This new yacht has arrived at Portsmouth on her return from her experimental cruise to Gibraltar, the object of the trial being solely to test the sea-keeping capacity of the vessel. Only nine out of her eighteen boilers were used, and until the last day no attempt was made to exceed 14 knots, and then, without lighting up any additional boilers, the speed was increased to 15 knots. The weather was admirably suited for the trial, both for the ship and for the crew, as for thirty-six hours the vessel was in a strong breeze, which occasionally amounted to nearly half a gale.

The yacht left Portsmouth drawing 19 feet 3 inches forward and 19 feet 9 inches aft. She proceeded at 14 knots in fine weather until she reached Ushant, when she picked up heavy

weather, which continued until she reached Cape Finisterre. The westerly wind struck her directly on her starboard beam, and caused her to roll on an average 7 degrees. The heaviest roll, however, was 10 degrees with return roll of 13 degrees; but whereas, on the contractors' trials, the ship showed a sluggishness in righting herself in a heavy sea, this defect was found to have entirely vanished. The stability of the ship having thus been established, she was subjected to further tests, such as circling in the trough of the sea and bringing every point of the ship up to the force of the wind and sea, but, whether pitching or rolling, the vessel behaved admirably, answering her helm with precision and righting herself with promptitude.

On leaving the Bay of Biscay the ship ran into a succession of fog banks, and speed had to be frequently altered. Seven knots was the lowest reached, but occasionally the engines had to be stopped altogether when the fog became too thick. These intervals, however, never lasted more than a few minutes at a time. She left Portsmouth with 650 tons of coal on board, and when she reached Gibraltar it was found that she had an ample supply on board to take her home, while, what was no less gratifying to the engine-room department, it was ascertained that her water supply was also sufficient.

Throughout the trip the engines worked with the utmost smoothness, and at no time was there any vibration, while the boilers proved themselves so economical that, with 650 tons of coal in the bunkers, the yacht has a radius of 2,500 miles, as she had about 40 tons left when she arrived at Portsmouth. In the opinion of the officers of the yacht, the trial was a complete success.—" R. U. S. I."

Leviathan.—New first-class armored cruiser was launched on the 3d July. The vessel is of the same type as the *Drake*, built at Pembroke Dockyard, *King Alfred*, built at Barrow, and *Good Hope*, built at Fairfield. She is 500 feet in length between perpendiculars and 71 feet 3 inches in beam, with a displacement of 14,160 tons, indicated horsepower of 30,000, and a speed of 23 knots. The armament consists of two 9.2-inch, sixteen 6-inch quick-fire, fourteen 12-pounders quick-fire, and several lighter

guns. The 9.2-inch guns will be mounted in separate barbettes, and the 6-inch guns in casemates, the protection being afforded by 6-inch armor of hard steel. Water-tube boilers of the Belleville type will be fitted to give an indicated horsepower of 30,000, the measured-mile speed in an eight hours' trial is to be 23 knots, and the continuous sea speed in smooth water 21 knots. The capacity of the coal bunkers will be 2,500 tons, and 1,250 tons will be carried at the speed trials.—" R. U. S. I."

Cornwallis.—On the 17th July, this new first-class battleship was launched from the works of the Thames Iron Shipbuilding Company, Blackwall. The *Cornwallis* is one of six vessels now building, the class taking its name from the *Duncan*, which is being built by the same company, and was launched in March last.

In general constructive details the *Cornwallis* follows the usual methods employed for ships of this class in the Navy. She is built on the usual bracket-frame system, with wing passages on each side to be used for holding coal. She has a double bottom amidships, with watertight flats at the ends of the vessel, thus having a double bottom from end to end. The armor is of Krupp cemented steel, but of English make. The side protection consists of a belt which extends from the stem to within 140 feet of the stern. The belt is 14 feet in maximum depth. It is 7 inches thick amidships, and tapers to 3 inches thick at the forward end. It has a vertical extension of 5 feet below the water line and 9 feet above at the designed load draught, being carried to the height of the main deck for a length of 286 feet. Between the armor deck and the belt deck there is a screen bulkhead aft, which joins the after barbette to the side armor, and abaft this is 1½-inch mild-steel plating in three thicknesses. The armored deck is arranged according to the principle now adopted in ships of this class, its sides meeting the lower edges of the belt. It has sufficient curve to rise 2 feet 6 inches above the water line amidships, and is 2.5 inches thick. The main deck is 2 inches over the citadel, thus adding to the protective features. The two barbettes are circular in plan, and are placed on the fore-and-aft center line. The armor on them has a maximum thickness

of 11 inches, and runs to a height of 3 feet above the upper deck.

There are eight watertight casemates on the main deck and four on the upper deck, all of Harveyized armor on the outside, and having armor plating at the back to protect the guns' crews from explosive shells. The vessel is fitted with twin screws, the propelling engines being supplied by the company's works at Greenwich. They are triple-expansion engines with four vertical cylinders, each of the collective horsepower of 9,000, giving an aggregate of 18,000 horsepower. The cylinders are 33½ inches, 54½ inches and 63 inches in diameter, with a stroke of 4 feet, and the number of revolutions 120 per minute when developing 18,000 indicated horsepower. There are two main condensers, having a cooling surface of 19,000 square feet. There are twenty-four Belleville boilers, having a total collective heating surface of 43,260 square feet and a fire-grate surface of 1,375 square feet.

The *Cornwallis* is to be fitted as a flag ship, accommodation being provided for an admiral and officers, with a total complement of 778 officers and men. Her dimensions are as follows: Length over all, 429 feet; length between perpendiculars, 405 feet; beam, extreme, 75 feet 6 inches; depth, top of keel to upper deck, 43 feet 9 inches; draught of water, mean, 26 feet 6 inches; displacement at that draught, 14,000 tons; indicated horsepower, 18,000; speed, 19 knots. Her armament comprises four 12-inch breech-loading guns in barbettes, twelve 6-inch quick-firing guns in casemates, ten 12-pounder 12-cwt. quick-firing guns, six 3-pounder quick-firing guns, eight .303-inch machine Maxims, one 12-pounder 8-cwt. for boats, one 12-pounder 8-cwt. for field, and four submerged torpedo-tubes.—"R. U. S. I."

Exmouth.—Was floated out at Messrs. Laird's works at Birkenhead, on 31st August. The great advantage of the *Exmouth* class as compared with former vessels is, although of slightly inferior armor protection, that they are longer on 1,000 tons less displacement, being the longest battleships ever built for the Navy. With engines of 18,000 horsepower —by far the most powerful ever fitted into a battleship—they

are expected to reach the high speed of 19 knots, which enables them to compete in mobility with many a so-called cruiser. The main propelling machinery, constructed at the Birkenhead Ironworks, consists of two sets of engines of the triple-expansion inverted type of the latest design. Each set is placed in a separate engine room. The cylinders are 32½ inches, 54½ inches and 63 inches diameter, 48 inches stroke. The boilers, twenty-four in number, are of the Belleville type, working at a pressure of 300 pounds, and are placed in three separate watertight compartments.

Moorhen.—This shallow-draught twin-screw gunboat, a sister to the *Teal*, which was described in the last number of the JOURNAL, was launched on Tuesday, the 13th August, from the yard of Messrs. Yarrow and Co., Limited, Poplar, and went through her official trials on the 21st. The guaranteed speed of 13 knots was maintained for three hours with open stokehold and without the necessity of forced draft, and during one hour wood fuel alone was used. The speed trial was made *en route* to Sheerness, and for more than two-thirds of the trial she steamed against a 25-knot wind. On arrival at Sheerness the guns were placed on board, and she then proceeded to sea again to carry out the gun trials. The draught of the vessel was 2 feet 3 inches, with a load of 40 tons on board. This vessel is built in floatable sections, and she will now be immediately disconnected for shipment abroad.

Syren.—The torpedo-boat destroyer *Syren*, the last of a series of thirteen vessels supplied by Palmer's Shipbuilding Co., has carried out her full-power trial at Portsmouth. The revolutions were 382.9 starboard and 380.2 port, and the total indicated horsepower was 6,708. The air pressure was 3.6 inches, and the mean speed for three hours was exactly 30 knots. During the early part of the trial the vessel made six runs over the measured mile in Stokes bay, when the mean indicated horsepower was 6,689, and the speed 29.812 knots.

On the coal-consumption trial, at a speed of 18 knots, with two boilers in use out of four, the horsepower developed was 1,224; coal expenditure, 2.2 pounds per horsepower per hour.

"It would be well to discover how far these trials afford true

criteria as to what we may legitimately expect from these boats when in commission. It was the *Kangaroo*, the immediate predecessor of the *Syren*, that, when still in the contractors' hands, carried out a three hours' trial at her full-load draught, and then we ascertained that the true speed of a 30-knot destroyer is 27½ knots. Then we have gone on the assumption that 12 or 13 knots is the economical speed of a 30-knot destroyer, but last Friday the *Syren* did a 12-hours' run at 18 knots with only 1,224 horsepower, and burning only 2.2 pounds of coal per horsepower per hour. But she will never achieve the same result at sea. At a trial of this sort the end and aim of the contractors is to show a small coal bill. If they are continually cleaning the fires out, they will burn more coal, and so, as in the case of the *Syren*, if they do not clean out the fires clinker will form. But as you cannot have clinker and coal in the same place, it follows that the more clinker the furnace holds the less coal will be there. And so it happened that whereas there was no air pressure in the first hour of the trial, in the twelfth hour there was an inch and a-half. Clearly you cannot accept that as a sea-going trial. The figures merely show what can be done under impracticable conditions."—Portsmouth Correspondent "Naval and Military Record."

Launch of English Submarines.—The first of the submarine boats being built for the British Admiralty has been launched. In addition to the five boats of the Holland type there is also, it is understood, a submarine of an English design being built to the order of the Admiralty, and it is rumored that several more will be provided for in next year's naval estimates. The Admiralty is now convinced of the utility of these boats, and an effort is to be made to get on a level with France in this matter. At the present moment the French have thirty-four in various states of manufacture—twenty-nine electric submarines and five submersibles. While the British boats will not be quite so fast as some of the French boats, they are expected to be superior in other ways, such as being able to rise and disappear more quickly. The dimensions of the five boats of the Holland type are 63 feet 4 inches over all and 11 feet 9

inches beam, with a displacement when submerged of 120 tons. One torpedo-expulsion tube is formed at the extreme forward end of the boat, and four of the 18-inch Whitehead torpedoes will be carried. The gear is being arranged so that the torpedoes may be discharged while the boat is stationary or running at any speed and when the vessel is awash or submerged.

Ingress and egress will be through a conning tower of armored steel, 4 inches thick and 32 inches in external diameter, fitted with observation ports. The propulsion of the vessel awash is by a gasoline engine with four single-acting cylinders, water-jacketed. The speed may be varied from 200 to 360 revolutions a minute, giving the maximum horsepower of 190. The boat will have only one propeller. The speed awash is expected to be 8 knots, and fuel is to be carried for a radius of 400 miles at that speed.

When the vessel is submerged, propulsion is by an electric motor, which, like the gasoline engine, drives the shaft from the propeller through gearing with clutch connection. This gearing enables both the gasoline engine and the motor to be at a lower level than the shaft, which is on the center line of the boat. For diving, the boat will be fitted with a horizontal as well as a vertical rudder; while, at the same time, a simple system of automatically arranging the disposition of the water ballast overcomes any lack of horizontal stability consequent upon the diving action. Automatic means also determine the angle of diving or of rising to the surface, and obviate submergence to excessive depths. By a special arrangement, a view of the surface from a depth that prevents the submarine being seen can be obtained.—"Marine Review."

NOTE.—In the quotation from the "Engineer," on page 705 of the last number of the JOURNAL, the stroke of the *Minerva* was inadvertently given as 3 feet. It should have been 3 feet 3 inches.

ITALY.

The following ships have been added to the effective strength of the Italian fleet, or will be during the year:

First-class battleships—*Emanuele Filiberto, Ammiraglio Saint-Bon.*

First-class armored cruisers—*Varese, Giuseppe-Garibaldi.*

Second-class cruiser—*Puglia.*

Torpedo cruisers—*Agordat, Coatit.*

Torpedo-boat destroyers—*Aquilone, Borea, Dardo, Freccia, Lampo, Nembo, Strale, Turbine, Euro, Ostro.*

Cistern-ship—*Bormida.*

The following ships have been struck off the effective list: *Città-di-Genova, Diligente, Vigilante.*

The following table shows the state of advancement, the cost, and approximate date of completion of ships under construction:

Type.	Name.	Under construction at	Date of completion.	Cost, lire.	Amount voted in present estimates.	Rate of construction, expressed in twentieths.
First-class battleships	*Benedetto-Brin*	Castellamare	1905-06	29,964,000	7,546,330	6
	Regina-Margherita	Spezia	.....	29,875,000	7,379,895	6
	Emanuele-Filiberto	Naples	1900-01	22,151,847	876,000	17
First-class armored cruisers	*Francesco-Ferruccio*	Venise	1903-04	15,545,862	4,776,078	9
	Giuseppe-Garibaldi	Gênes (Ansaldo)	.....	15,913,144	414,240	finished
	Varese	Livourne (Orlando)	.....	15,936,144	804,534	...
Torpedo-avisos	*Agordat*	Naples	.....	3,113,058	23,000	...
	Coatit	Ditto	.....	3,113,058	19,000	...
	Dardo	Elbing (Schichau)	.....	1,161,025	184,900	...
	Strale	Ditto	1900-01	1,161,025	208,334	19
Torpedo-boat destroyers	*Ostro*	Ditto	.....	1,262,325	260,434	18
	Euro	Ditto	.....	1,262,325	260,434	17
	Nembo	Naples (Pattison)	.....	1,227,325	297,000	finished
	Turbine	Ditto	1900-01	1,227,325	320,434	17
	Aquilone	Ditto	.....	1,227,325	320,434	14
	Borea	Ditto	.....	1,227,325	320,434	11
	Atlanta	Ditto	.....	933,092	333,092	10
Tugs	*21*	Venise (Layet)	.....	115,809	55,809	8
	21	Chioggia (Poli)	.....	115,809	55,809	6
Cistern ship	.....	Venise (Vianello)	.....	103,809	43,809	9
Total					24,500,000	

—"Stato di Previsione della Spesa del Ministero della Marina."

Regina Margherita, first-class battleship, which was launched at Spezia, on 30th May, is the most powerful ship yet built for the Italian Navy. Her principal dimensions are: Length, 426 feet 6 inches; beam, 78 feet; draught, 27 feet 4 inches; displacement, 13,426 tons. The two triple-expansion engines, fed by twenty-eight Niclausse water-tube boilers, calculated to de-

velop 19,000 indicated horsepower with forced, and 16,000 indicated horsepower with natural draft, are expected to develop a speed between 19 and 20 knots. The extreme coal capacity is 2,000 tons, the bunkers being arranged longitudinally, as an additional protection to the vital parts of the vessel. The hull is built of 5,000 tons of steel, wood being entirely excluded. The thickness of the armored belt varies from 4 to 6 inches, the armor of the barbettes being 8 inches, with 8-inch hoods for the guns, and that of the armored deck 3 inches. Along the waterline, however, the conjunction of the armored deck with the belt gives a thickness of nearly 9 inches. The principal armament consists of four 12-inch guns in barbettes, situated one forward and one aft, and the secondary armament of four 8-inch, twelve 6-inch quick-fire guns, eighteen 3-inch quick-fire guns, and eight 3-pounders, with four machine guns. The vessel is also furnished with four torpedo tubes, two of which will be submerged. The machinery was constructed by the Ansaldo firm at Genoa. —"R. U. S. I."

Emanuele Filiberto.—The following are the details of the trials of this new first-class battleship: The ship, which has a displacement of 9,800 tons, is 344 feet 6 inches long, with a beam of 69 feet 4 inches and a mean draught of 24 feet 9 inches. Her twin-screw engines are of the ordinary vertical triple-expansion type, in two separate engine rooms, the boilers, of the cylindrical type, being placed six forward and six abaft the machinery. According to the contract the engines were to develop 9,000 indicated horsepower under natural draft during a six hours' run, and under forced draft during one and a-half hours' run they were to develop 13,500 indicated horsepower, making 112 revolutions. The screws are four-bladed Griffith's, and the total weight of engines and boilers, with water in the latter at steaming level, is 1,253 tons, giving 205 pounds for each indicated horsepower. At the six hours' natural-draft trial the mean power developed was 9,981, nearly 1,000 in excess of contract, the engines making 94 revolutions, giving a speed of 16.8 knots. During the full-speed trial which was held three months later, although the engines developed 13,630 indicated horsepower,

the engines only made 97.7 revolutions, giving a speed of 17 knots, or more than a knot under the guaranteed speed. The ship's bottom was very foul at the time, but this did not account for the unsatisfactory working of the engines.—" R. U. S. I."

Agordat.—The new torpedo aviso *Agordat* has completed her trials at Naples. The ship was built at the Royal Dock Yard at Castellamare, her dimensions being as follows: Length, 287 feet 6 inches; beam, 30 feet 6 inches; displacement, 1,313 tons, with a mean draught of 11 feet 11 inches. Her armament consists of four 4.7-inch quick-fire guns, eight 6-pounder quick-fire guns, with two 3-pounders and two torpedo tubes. Her engines, which drive two Griffith screws, according to the contract were to develop 4,400 indicated horsepower under natural draft, with a coal consumption not to exceed 1.98 pounds per horsepower per hour, and to develop 7,500 indicated horsepower under forced draft for three hours. At her natural-draft trial the engines developed 4,670 indicated horsepower, the engines making 190 revolutions and giving a speed of 18.8 knots. At the full-speed forced-draft trial the engines developed 8,550 indicated horsepower, making 232 revolutions and giving a mean speed of 22.2 knots, the maximum speed attained being 23 knots. Steam is provided by eight water-tube boilers of the Blechynden type, which work at a pressure of 200 pounds to the square inch. The boilers are in two groups of four each in separate stokeholds, with a funnel for each group. The total grate surface is 376 square feet, the total heating surface being 20,468 square feet. The total weight of the engines and boilers is 285 tons.

Submarine Boat Trials.—A number of successful trials have been carried out with the submarine boat *Delfino*. The *Delfino* was built at Spezia in 1896, and several successful series of experiments were carried out with her; but in one of her dips she fouled the *Maria Pia's* bottom and could not be cleared until the battleship weighed and shifted berth. After this her trials were given up, but they were recommenced a short time ago. She is constructed of steel in the form of a cigar, is about 72 feet long, with a diameter of 8 feet 6 inches. When completely immersed she has a displacement of about 107 tons. The

motive power is furnished by a battery of 300 accumulators, which give her a speed of from 8 to 9 knots on the surface of the water. She is driven by a screw, there being two small screws in addition for submerging her or sending her to the surface. She carries two torpedo tubes forward. The provision of air is sufficient for twelve men for seven or eight hours. The cost of the *Delfino* is 300,000 liré. The *Delfino* is to be fitted with a new periscope, the invention of two engineers in the Royal Navy—Signori Russo and Laurenti. The new instrument is called the cleptoscope, and it is claimed for it that while the tube, which is visible above the water, is only 5 inches in diameter, it has a field of view of 60 degrees, which is without distortion and extends to the horizon. The original French periscope has only a field of 3 or 4 degrees, and with it it is extremely difficult to locate objects, while in the latest pattern the tube is over 13 inches in diameter, while the objects in the field are said to appear blurred and distorted.—Rivista Marittima, Italia Militare e Marina, and Mittheilungen aus dem Gebiete des Seewesens.

Ammiraglio di S. Bon.—The machinery trials of this first-class battleship have been satisfactorily completed. For her dimensions see page 788.

The propelling machinery, built by Ansaldo and Company, Geneva, comprises vertical, twin-screw, triple-expansion engines, and twelve return-tube cylindrical boilers.

The engines are in two water-tight compartments separated by a central longitudinal bulkhead, and the boilers in two groups of six each, one forward and the other abaft the engines. Each group of boilers is separated by a longitudinal bulkhead, making three boilers in each compartment.

The cylinders of the main engines are 44, 66 and 99 inches in diameter, and the stroke of pistons 48 inches. The cranks are at angles of 120 degrees with each other, and the order of cylinders from forward is high, intermediate and low pressure. The contract required that the indicated horsepower maintained at sea for 1½ hours should be 13,500, with an air pressure of 1.6 inches of water and 155 pounds pressure in the boilers, the revo-

lutions not to exceed 112; and with natural draft, 9,000 indicated horsepower for six hours.

The valve gear is of the Stephenson link type, with piston valves for the high-pressure, and double-ported slide valves for the intermediate and low-pressure cylinders.

The boilers are 13.44 feet diameter and 9.84 feet long, and have three corrugated furnaces each. There is a separate combustion chamber for each furnace. The grate surface is 846, and the heating surface 23,681 square feet.

The screws are four bladed, 16.25 feet diameter and 20.5 feet mean pitch; the fraction of pitch is .366.

The weight of propelling machinery with water in boilers and pipes, spare parts and stores is 1,340 tons.

The results of her contract trials are given below:

	Natural draft.	Forced draft.
Date of trial	June 26, 1901.	May 23, 1901.
Duration of trial, hours	6	1.5
Number of boilers in use	12	12
Steam pressure in boilers, pounds	149.7	150
at engines, pounds	148	146
Air pressure in fire rooms, inches	.34	1.26
Revolutions per minute	94.4	104
Indicated horsepower	10,407	14,296
Speed, knots	17.47	18.3
Days out of dock	158	14
Mean draught of water, feet	25	24.93
Displacement, tons	9,950	9,908
Coal per indicated horsepower, pounds	1.87	2.18

—"Rivista Marittima."

JAPAN.

Shirakumo, torpedo-boat destroyer, built for the Japanese Government, was launched on October 1. The vessel, which is the first of two now completing, has a guaranteed speed of 31 knots, carrying a load of 40 tons. The length is 216 feet 9 inches, and the beam 20 feet 9 inches. The engines are triple-compound, with four cylinders, and there are four boilers of the Thornycroft-Schultz type. The armament is the same as that of British war vessels of this class. The keel of this vessel was

laid on February 28 last, so that she has been built practically in seven months.

Warships for the Japanese Navy.—As an indication of the manner in which the Japanese Government is increasing its already formidable navy, there are at the present time no less than eleven vessels of different types either being built or nearing completion for the Japanese. Of these the cruiser *Niitaka* and the torpedo-boat destroyers *Harusame*, *Murasame*, *Hayatori* and *Asakiri*, are being constructed at Yokosuka, and the cruiser *Tsushima* at Kure. Each of the above-named cruisers will be of 2,800 tons displacement, with a speed of 20 knots per hour, their principal armaments consisting of 4.7-inch guns. The battleship *Mikassa*, which is of 15,200 tons displacement, and has a speed of 18 knots per hour, is being completed at the works of Messrs. Vickers, Sons and Maxim, at Barrow-in-Furness, England. The torpedo-boat destroyers *Akatsaki*, *Kasumi*, *Asashiroo* and *Shirakumo* are also being built in England. These vessels are of 310 tons displacement, 6,200 horsepower, and are expected to develop a speed of 32 knots per hour, and, in addition to being provided with an equipment of torpedoes and tubes, will each be armed with one 12-pounder and five 6-pounder quick-firing guns. Some of the vessels enumerated will be ready for sea during the present year, and the whole of them by the end of next year.—"Marine Record."

MEXICO.

The work on two men-of-war for the Mexican Government, at Lewis Nixon's shipyard, at Elizabethport, N. J., is progressing rapidly. The new vessels are about the size of the *Machias* class. They are each 200 feet long, 33 feet beam, and displace 1,000 tons on a draught of 10 feet. They are of steel throughout, with quarters arranged for comfort in tropical waters. The vessels will carry coal enough to steam 7,000 miles. They will have two triple-expansion engines with a total of 2,400 indicated horsepower, and water-tube boilers, and are expected to have a speed of 16 knots.

RUSSIA.

Retvizan, first-class battleship, possesses special interest because of the fact that she is the first important foreign battleship to be constructed in an American shipyard. The first foreign orders for warships of the modern type were those given by the Japanese Government to the Union Iron Works of San Francisco and the Cramp Shipbuilding Company of Philadelphia, for two high-speed cruisers. Both of these vessels have been built and delivered, and each of them considerably exceeded the contract speed. Following closely upon the trials of these vessels an order was placed by the Russian Government at the Cramps' yard for the construction of a battleship and cruiser. The latter had her trials last year and achieved a speed of more than 23 knots an hour, thus taking rank as one of the very fastest vessels of her kind in the world. The battleship has undergone her builders' trial, on which it is reported she attained an average speed on a 12 hours' trial of 18.18 knots per hour. This speed was made on the run from the Capes of the Delaware to Boston. After the screw standardization runs at 18 knots over the measured course, for which it was ascertained that 125.47 revolutions per minute were required, the vessel returned to Philadelphia.

Continuing on the twelve-hour test, after leaving the measured course, on her return trip to the Capes, the average number of revolutions for the entire twelve-hour run was 124.9. This reduction in speed was caused by the giving out of a faulty tube of No. 11 boiler, which boiler was out of use for three hours. In that relatively short space of time the fire was drawn from the disabled boiler, the faulty tube replaced and the boiler connected. Before and after this occurrence the engine was keeping up the average number of revolutions made over the measured course. During the last hour of the twelve-hour trial an account of coal burned was kept. When the engines were developing 18,300 horsepower, with the auxiliaries, the consumption amounted to 1.8 pounds per horsepower per hour. During this trial the boilers steamed freely, and although the blowers were running there was no air pressure shown by the gages. The blowers assisted

only by drawing the air down to the furnace level. The engines worked remarkably well, no jar and no heated bearings, every part, including auxiliaries, working smoothly.

As soon as the twelve-hour test had been completed a trial of twenty-four hours at 10 knots was made, to determine the radius of action at that speed. The amount of coal consumed during the twenty-four-hour test showed that a radius of 8,800 knots was obtained with 2,000 tons of coal, which is about the full capacity of her bunkers. This trial was made with only the after group of eight boilers in use, and besides the steam used for the main engines, power was furnished for all the electric machinery and auxiliaries of every kind, and the evaporators were also used to make up the fresh-water loss.

Another trial, to determine the most economical coal consumption, was made at the termination of the 10-knot trial. For this a speed of about 100 revolutions of the engines was taken, using all the boilers with slow combustion. This trial determined that the amount of coal per horsepower per hour at this speed was 1.55 pounds, the engine developing 7,820 horsepower. Several minor tests were made during the trial. One was of the evaporators, which developed a capacity 30 per cent. above what the contract called for. The engines were also reversed from full speed ahead to full speed astern, to the entire satisfaction of the Russian Board.

The *Retvizan* is a first-class battleship of 12,700 tons displacement. In size and speed she may be compared with our own vessels of the *Maine* class.

	Maine.	*Retvizan.*
Length, feet	388	374
Breadth, feet and inches	72–2½	72–2
Draught, feet and inches	23–6	25
Displacement, tons	12,300	12,700
Battery	4 12 inch.	4 12-inch.
	16 6 inch.	12 6-inch.
	6 3-inch.	20 3-inch.
	8 6-pounders.	20 3-pounders.
	10 small caliber.	6 1-pounders.

The *Retvizan* is protected by a belt of armor 9 inches in thickness which extends from 4 feet below the water line to 3 feet

above, reaching to the level of the protective deck. The latter is 2 inches in thickness on the flat and 4 inches on the slopes. It commences to slope at the level of the top of the 9-inch belt, and descends to a junction with the bottom of the belt below the water line. The space between the slope and belt is occupied by coal bunkers. A projectile, before penetrating the engine or boiler rooms, would consequently have to penetrate 9 inches of Krupp steel, from 6 to 10 feet of coal and 4 inches of sloping Krupp armor. The protective deck is carried the full length of the vessel, and curves down to meet the stem and stern. At the stem it is merged into the framing of the ram bow, and being 3 inches in thickness and of turtle-back form it gives enormous stiffness to the ram, and would assist in transmitting the shock of ramming to the whole structure of the vessel. Above the 9-inch belt amidships and between the protective and the gun decks is worked another belt of armor 6 inches in thickness. This will prevent rapid-fire shells from penetrating and bursting beneath the guns on the gun deck above.

The bulk of the rapid-fire armament is carried on the gun-deck. Amidships, above the 6-inch belt of armor above referred to, is a battery of eight 6-inch rapid-fire guns in casemates, each gun having a considerable train forward and aft. The casemates are protected by 5 inches of steel and the armor is carried athwartships at each end of the battery as a safeguard against raking fire. The 9-inch and 6-inch belts of armor are also carried athwartships to connect with the armor of the barbettes, thus forming a completely inclosed armored citadel amidships. At the four corners of the superstructure deck, above the central citadel, are four 6-inch rapid-fire guns, of which the forward pair can be trained dead ahead and the other two dead astern. These guns are completely protected with armor varying from 5 inches to 2 inches of steel.

Forward of the central battery on the gun deck are four 3-inch rapid-fire guns, each with a protection of 2 to 3 inches of casemate armor, while aft of the battery are six rapid-fire guns of the same caliber. The main deck is flush throughout the ship, and is broken only by the amidship superstructure.

Forward and aft of the superstructure are two elliptical balanced turrets, carrying 10 inches of Krupp steel. In each turret are placed two 12-inch, 40-caliber, breech-loading rifles of the standard type manufactured by the Russian Government. Both the turrets and the guns are operated electrically. The roof of the turret, which is of 3-inch Krupp steel, is slightly curved to clear the muzzles of the guns when the latter are elevated or depressed.

There are twenty-six smaller guns mounted on the boat deck, the bridge and the fighting tops. Forward and aft on the boat deck there are distributed twelve 3-inch rapid-firers, while on the forward and after bridges, immediately above these, are eight others of the same caliber. These guns have a range of fire from dead ahead to abeam. There are also six 1-pounders in the two fighting tops. With such a numerous rapid-fire battery, a specially large supply of ammunition has to be carried, 2,400 rounds being supplied for the 6-inch guns alone. Three hundred and eight rounds are carried for the 12-inch guns. Electric ammunition hoists are installed throughout the ship.

As compared with our battle ship *Maine*, it will be seen that the main battery is not so powerful, our vessel, which is about the same displacement, carrying sixteen as against twelve 6-inch rapid-fire guns. This, however, is somewhat offset by the larger number of 3-inch rapid-firers installed on the *Retvizan*. The 6-inch rapid-fire guns are of 45 calibers, or 5 calibers less than our new 6-inch guns.

The engines are two in number, located in water-tight compartments. They are triple expansion. The cylinders are 38½, 59 and 92 inches in diameter, and the stroke is 42 inches. When operating at 120 revolutions per minute the indicated horsepower will be about 8,100 each, making a total of 16,200. Stevenson link-gear is used. The high-pressure cylinder is fitted with one piston valve, the intermediate with two, and the low-pressure cylinder with four. A separator of a centrifugal type is placed in the main steam line between the boilers and the engine-throttle valve. The condenser is of the surface type, with a centrifugal circulating pump, and the Snow admiralty-type air pump. The discharge from the air

pump passes through a sponge filter placed beneath the condenser, then into the hotwell. From the hotwell the water is taken by a vertical pump and forced up to a feed tank placed over the engines. From the feed tank the water passes by gravity through a closed heater to the suction line of the main boiler-feed pumps, which are located one in each stokehold on the starboard side. The auxiliary pumps are located on the port side, one being placed in each stokehold, as is the case with the main-feed pumps. In the discharge line of both the main and auxiliary-feed pumps is a grease extractor, consisting of filters of burlap or sacking material.

The boilers are twenty-four in number, with a heating surface of 2,222.64 each, making a total of 53,343.36 square feet heating surface. The grate surface is 55.56 for each boiler, or a total of 1,333.58 square feet. The boilers are divided into groups of six, separated by watertight compartments. Each group consists of four boilers, placed in pairs opposite each other, with a firing floor between; the remaining two boilers are placed facing either the forward or after bulkhead, as the case may be.

The coal bunkers are between the boiler room and the ship's side, and extend the whole length of the boiler room and up to the protected deck. The stowage capacity of the bunkers is 2,200 tons, but the running capacity would be about 2,000.

The boilers are connected to three smokestacks, eight boilers to each stack. The tops of these stacks are 100 feet above the grate surface, and their diameter is 9 feet 10 inches.

New Cruiser.—The machinery for the new cruiser of 6,300 tons displacement, sister ship to the *Bogatyr*, now under construction at St. Petersburg, has been ordered of the Franco-Russian Manufacturing Company from plans submitted by the Vulcan Works. Her three engines are estimated to develop not less than 19,500 horsepower, giving her a speed of 23 knots, with a normal draught of 20 feet 6 inches. The cranks will be fitted with Schlick counterpoises. The engines will receive steam from sixteen water-tube boilers of the Normand pattern, under a working pressure of 256 pounds to the square inch. The con-

densers of sea water will be fitted for supplying feeding and drinking water. The engine-room ventilation is electrical. The boilers are in three groups, two longitudinal of six each and in each compartment, and one of four transversal. Each of these compartments will be furnished with a separate funnel. The heating surface of these sixteen boilers collectively is estimated at 49,496 square feet, or 2.5 square feet to each indicated horsepower, which may be taken as nominal, considering that the vessel is fitted with heaters for the feeding water. The grate area will be 988.8 square feet. The water-heating pipes will be of a diameter of 36 millimeters and a thickness of 3 millimeters. In each boiler compartment there will be from six to eight steam fans, receiving air from shafts communicating with the upper deck.

The expeniture of coal during the two official trial trips of six hours each is contracted for not to exceed 2 pounds to each indicated horsepower. In case of its exceeding 2½ pounds by 8 per cent. the company is liable to forfeit 37,500 roubles (£6,000), if by 12 per cent. 78,750 roubles (£12,600), and if 14 per cent. 105,000 roubles (£16,800). The cost of the machinery and all accessories is estimated at 2,900,000 roubles (£624,000), the entire weight not to exceed 1,272 tons, under penalties both for excess and deficiency ranging to 68,500 roubles (£10,960) for 9 per cent.—"Jour. R. U. S. I."

Almaz and Ochakov.—A cruiser, to be called the *Almaz*, has been ordered of the Baltic Shipbuilding Works. Her displacement is to be 3,200 tons, and her engines have been ordered of the same works at a cost of 1,000,000 roubles (£160,000). The cruiser *Ochakov*, in process of construction at the Government yard at Sevastopol, is to have a displacement of 6,250 tons. Her engines, of 19,500 horsepower, have been ordered of one of the southern factories. Her special feature with regard to armor is that the protected deck, of about 2½ inches in thickness, is supplemented by armored tubes protecting the supply of ammunition to the guns. The hull will be made of Siemens-Martin steel, and there will be two steel masts with tops. The speed contracted for is 23 knots, and the armament will consist of twelve

6-inch quick-fire guns and twenty-two small quick-firers.—" Jour. R. U. S. I."

Peresviet.—12,674 tons displacement. This vessel, of which the construction was begun in November, 1895, at the Baltic Works, St. Petersburg, forms with the *Oslayba* and the *Pobieda*, a group of three very nearly similar vessels. Their construction having been begun after that of the *Poltava*, *Petropalovsk* and *Sevastopol*, and before that of the new battleships *Revitzan*, *Borodino* and *Cesarevitch*, they can only be considered as an intermediate type between these two classes of battleships. They constitute a special hybrid class, as will be seen from the following description.

With a displacement of 12,674 tons, the *Peresviet* can carry a normal coal supply of 1,063 tons, and this amount can be increased to 2,060 tons at the total capacity. The motive power is provided by three similar engines and by thirty Belleville boilers in three fire rooms. It is expected that these will give a speed of 18 knots with 14,500 indicated horsepower.

The protection of the vessel is provided by a water-line armor belt of hardened steel of 25 centimeters maximum thickness, and extends over the middle body for six-sevenths of the length of the vessel, with transverse bulkheads forward and aft of 25 centimeters in thickness. It should be noted that on the *Pobieda*, whose construction was commenced before that of the *Peresviet*, the armor belt extends from end to end of the vessel, with its thickness reduced to fifteen centimeters at the extremities. A protective deck from 102 to 70 millimeters in thickness extends from end to end of the vessel.

The light belt, which is fitted above the water-line belt over the middle portion of the vessel and forms the base of the armored casemates, has a thickness of 15 centimeters, the same as these casemates. Finally, the two large turrets for the 25-centimeter guns are protected by armor 23 centimeters in thickness, with the armored barbettes descending to the armored deck and assuring the necessary protection for the ammunition hoists.

The main battery consists of four 25-centimeter guns placed in pairs in two turrets, situated in the midship fore-and-aft line

of the vessel, one forward, with a height above the water line of 10.6 meters, and one aft, with a height above the water line of 7.9 meters.

The secondary battery comprises ten 15-centimeter guns placed in casemates as follows: Two on each side on the main deck at the forward and after corners of the thin belt, three on each side on the gun deck, of which two on each side are directly above the guns on the main deck, the casemate armor of the lower guns being extended to afford protection to the upper guns, and one amidships on each broadside. Finally, one is situated in the extreme bow, to be used as a bow-chaser.

As a light battery the vessel carries twenty rapid-fire guns of 76 millimeters caliber, half of them on the main and half on the gun deck, and twenty-seven 3-pounders, mounted on the superstructure and in the military tops. There are also six torpedo tubes, of which four are under water.

To sum up, the armament is well placed and well protected, but the guns forming the principal part of it are too weak for a battleship. The armor is equally well placed and of good thickness, but it still leaves one-seventh of the vessel unprotected at the water line.

The vessel has a large coal-carrying capacity, in common with a great many others of the Russian ships which are designed for a continuous passage to Asiatic waters. The percentage of the displacement allowed for this capacity being so much greater than that allowed on battleships of this type for other nations, it is not at all surprising that in obtaining it the speed of the vessel should be less, the main battery less powerful, and the secondary battery less numerous than is found in vessels of the same class in other navies. Nevertheless the compromise class of vessels represented by the *Peresviet* has a very great military value.—"Le Yacht."

Emperor Alexander III.—This battleship was launched at the Baltic Works on August 2, and will be followed very shortly by her sister ship, the *Borodino*. Her principal dimensions are as follows: Length over all, 397 feet; between perpendiculars,

375 feet 7.8 inches; beam, 75 feet 11.82 inches; mean draught, 25 feet 11.04 inches; displacement, 13,600 tons. The protection consists of an armor belt of Krupp steel, with a thickness of 9.02 inches at the water line, decreasing to 4.01 inches at the lower edge and to 7.01 inches at the upper edge, and extending from forward to the after armored bulkhead. The central redoubt has a thickness of 5.91 inches, while the transverse bulkheads are 9.06 inches in thickness. The curved armored deck, extending from stem to stern, varies in thickness from 2 inches to 4 inches; the slopes of the lower armored deck are protected by coal. The turret forward has a thickness of 10 inches, the top being 1.77 inches thick.

The motive power is supplied by two vertical, inverted, triple-expansion engines of 16,000 horsepower, which is expected to give a speed of 18 knots for twelve hours. The steam is supplied by water-tube boilers.

The normal coal supply of 1,250 tons will give a radius of action of 8,500 miles at 10 knots and of 3,000 miles at 18 knots.

TURKEY.

Reconstruction of the Turkish Battleship Mesoudie.—A very interesting work is just being carried out at Genoa, in connection with the reconstruction of the Turkish battleship *Mesoudie*. It will be remembered that her sister ship, the *Memdouhiye*, which was purchased for the British Navy at the time of the Russo-Turkish war, and renamed the *Superb*, was rearmed in 1890, and new propelling machinery fitted in her; but the single screw was retained.

The Turkish authorities, however, determined at all cost to have the vessel converted for twin screws, and Messrs. Ansaldo, of Genoa, to whom the work of reconstruction was entrusted, have carried out the necessary modifications in a very substantial way.

With a vessel not intended for twin screws, the attachment of the stern brackets to a stern not specially strengthened and constructed to receive them is likely to be a source of weakness, necessitating a stiff covering being fitted to the shafts, carried

from the V-brackets to the after ring of the stern tube, so as to tie them firmly to the hull and prevent any fore-and-aft motion. But as will be seen in Figs. 1 and 2, in the case of the *Mesoudie*, advantage has been taken of the existing screw opening to bring the propellers close together, thus reducing the leverage as much as possible. The stern brackets have an extra breadth of base attachment to the hull, and their weight and that of the stern shafting being well supported by the flange of the ⊥-shaped bar at the bottom of the stern frame, a very rigid structure is the re-

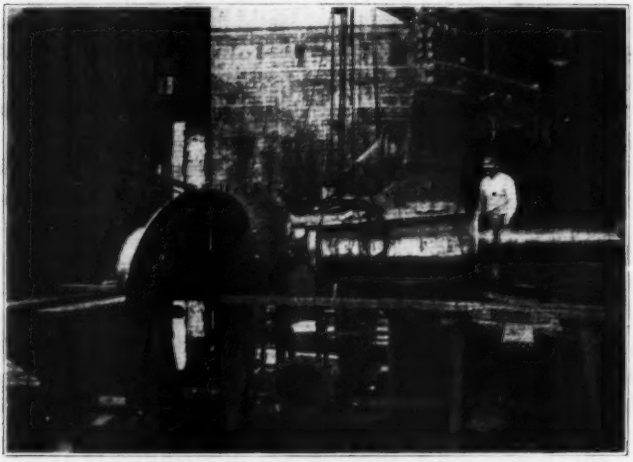


FIG. 1.

sult, and it was possible to dispense with the covering in of the shafts without fear of any undue vibration, or fore-and-aft movement of the V-frames.

Both the inner and outer bottoms were found to be in most excellent condition, and the vessel was so thoroughly well built and of such excellent material, that when she is completed she will be a most serviceable ship and good for many years of service.

The new propelling machinery consists of two sets of triple-expansion four-cylinder inverted engines of 11,000 horsepower,

the steam being provided by sixteen water-tube boilers of the Niclausse type, arranged in four groups of four boilers each. Both engines and boilers have been constructed by Messrs. G. Ansaldo & Co. in their shops at Sampierdarena, near Genoa, and it is noteworthy that this is the first set of machinery constructed in Italy the material of which (with the exception of the large shafts and the boiler tube) has been forthcoming in the country itself, the cast and malleable steel and the malleable cast iron being furnished by Messrs. Ansaldo's new steel works, and the special bronzes from their yellow-metal works, both situate at Cornigliano, Ligure.

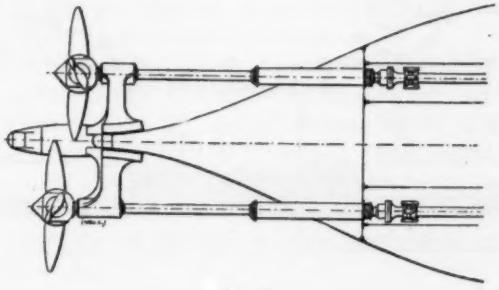


FIG. 2.

The armament is by Messrs. Vickers, Sons & Maxim, Limited, and consists of two 9.2-inch wire guns of 45 calibers, breech loading; twelve 6-inch wire guns of 45 calibers, breech loading and quick firing; fourteen 3-inch quick-firing guns; ten quick-firing 6-pounders and two 3-pounders, besides two light boat guns complete, with their carriages.

The 9.2-inch guns are mounted on a revolving platform on the upper deck, carrying a complete shield of hardened steel armor, 6 inches thick at the front and 3 inches at the back and sides. The twelve 6-inch guns are placed in the citadel and mounted on central-pivot carriages carrying a semi-circular shield of hardened steel armor, 4½ inches thick, which completely closes the gun aperture.

The vessel and her machinery are completed.—"Engineering."

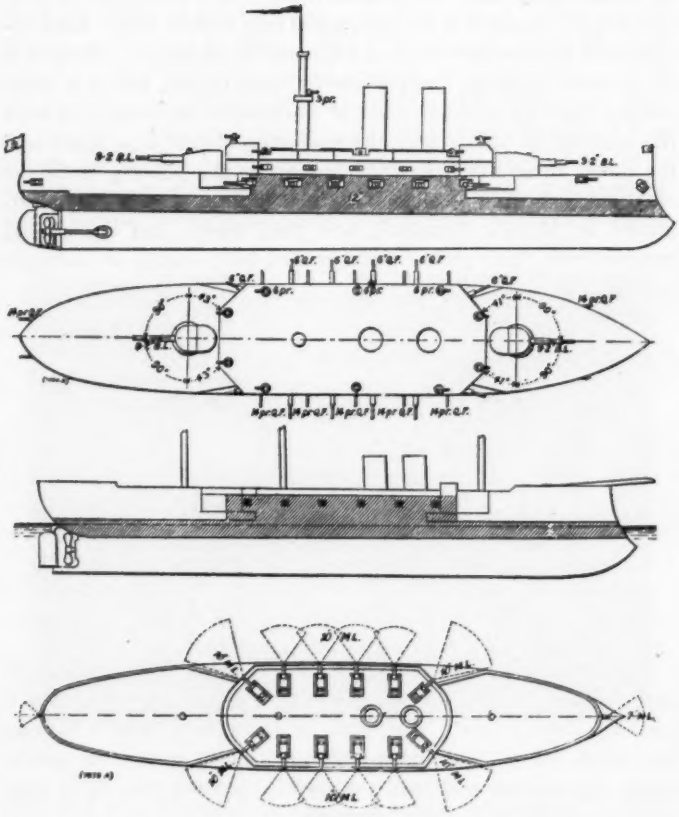


FIG. 3.

VENEZUELA.

The Government is going to add to the seven nearly worthless small vessels which it possesses at present one cruiser and two torpedo boats, which will be purchased in Germany.

MERCHANT STEAMERS.

La Savoie.—After very satisfactory trials at Belle Isle and at Havre, this new steamer of La Compagnie Générale Transatlantique accomplished her first voyage across the Atlantic in the record time of six days, ten hours and twenty minutes, maintaining a mean speed of 20.6 knots for the trip. The return trip was made in six days, thirteen hours and two minutes, also the best record time for the eastward voyage.

The following are the principal characteristics of the vessel as given in "Le Yacht": Length over all, 582 feet, 2.9 inches; between perpendiculars, 557 feet, 9.6 inches; beam, 59 feet, 8.59 inches; mean draught, 25 feet, 5 inches; displacement, 15,500 tons. Her total coal capacity is 3,100 tons, and her ballast tanks have a capacity of 1,200 tons. The hull is divided by eighteen transverse watertight bulkheads and one longitudinal bulkhead between the engines.

The engines are vertical, inverted, four-cylinder, triple-expansion; the cylinders being 44.5 inches, 80.3 inches, and two of 80.3 inches diameter, respectively, with a stroke of 66.9 inches. On the trials these engines, at 92 revolutions per minute, developed 23,000 horsepower, and gave a maximum speed of 22.65 knots.

There are sixteen single-ended four-furnace boilers, and one two-furnace Belleville boiler, the latter being intended for cargo handling purposes. This latter boiler has 59 square feet of grate surface and 1,862 square feet of heating surface.

The single-ended boilers are 17.06 feet in diameter, with furnaces 44¼ inches in diameter. These boilers have a total grate surface of 1,223.86 square feet, and a heating surface of 45,568 square feet. The two smoke pipes are oval in section, and have a height of 94⅜ feet above the grates.

The electric lighting is provided by 1,549 lamps of 5, 10 and

16-candlepower, the dynamos being driven by four Laval turbines of 75 horsepower each.

Additional data concerning this vessel can be found in No. 3 of the current volume, page 804.

The New German Atlantic Liner Kronzprinz Wilhelm.—The new twin-screw steamer *Kronprinz Wilhelm* arrived in New York on Wednesday. She left Bremen on September 17 and Southampton and Cherbourg the 18th. From the time of leaving Cherbourg harbor the steamer experienced head seas, with heavy southwesterly gales. On the 24th she made 575 knots, which the chief engineer claimed to be the best day's run ever made on an initial voyage. The time of passage was 6 days, 10 hours and 15 minutes. Total distance, 3,045 knots; average speed per hour, 19.74 knots. The new liner has, as equipped for service, cost within a few pounds of £650,000 sterling, while her sister ship, the *Kaiser Wilhelm der Grosse*, completed three years ago, cost £550,000, the difference being due to the greater cost of material and some effective improvements made in the equipment.

The *Kronprinz Wilhelm* is not quite so large as the *Deutschland*, the difference in length being in the engine room. Practically the only change made in the engines as compared with those of the *Deutschland*, is in the arrangement of the valve gear for the tandem engines. In the *Deutschland* a high-pressure cylinder is placed over each of the two low-pressure cylinders, and the piston valve of the high-pressure cylinder is actuated by means of a rocking lever pivoted on the cover of the low-pressure cylinder, and operated by separate links and eccentrics. In the new ship, however, the spindle of the high-pressure cylinder, still working on a lever pivoted to the cover of the low-pressure cylinder, is connected to the top of the spindle of the slide valves of the low-pressure cylinder, so that the one pair of eccentrics, with their gear, suffices for both low-pressure and high-pressure cylinders. The first intermediate cylinder is at the forward end of the engine, and the second intermediate at the after end, the four cranks and the reciprocating parts being balanced on the Schlick system. The two high-pressure

cylinders are 870 millimeters (34.2 inches) in diameter, the intermediate cylinders being 1,750 millimeters (68.8 inches) and 2,500 millimeters (98.4 inches), while the two low-pressure cylinders are 2,600 millimeters (102.3 inches), the stroke being 1,800 millimeters (70.8 inches).

The engines are to run normally at 80 revolutions, although 83 or 84 can easily be obtained; the normal indicated horsepower, which has already been developed on trial with a comparatively early cut-off, is 33,000. The speed attained on the trial, 23.34 knots, gives every promise of an interesting competition with the *Deutschland*, whose record speed is 23.51 knots. The crankshaft of the *Kronprinz Wilhelm*, is 610 millimeters (24 inches) in diameter, the thrust shaft 600 millimeters (23.6 inches), the tunnel shaft 580 millimeters (22.8 inches), and the propeller shaft 630 millimeters (24.8 inches), while the four-bladed propellers, of bronze, are 6,650 millimeters (21 feet 10 inches) in diameter, and of 10 meters (32 feet 9 inches) pitch. To enable the screw shaft to be withdrawn from the outside of the hull, a large flat coupling has been fitted to the propeller shaft, the weight of the coupling being about 11 tons. All the pumps are separate from the main engines, as well as the condenser, which latter has a length of 2,604 millimeters (8 feet 7 inches), with 1,910 square meters (20,559 square feet) of surface, this being, of course, the measurement of both the main condensers, while the auxiliary condensers are 1,600 millimeters (63 inches) long with 60 square meters (646 square feet) of surface. The air pumps are by Messrs. Weir and Cathcart, who have also supplied the feed pumps and feed heaters. There are twelve double-ended and four single-ended boilers, and these, unlike those of the *Deutschland*, where Howden's system is in use, are to be worked under natural draft with an open stokehold, as was the case with the *Kaiser Wilhelm der Grosse*. The boilers, which work to a pressure of 213 pounds per square inch, are 5,100 millimeters (16 feet 9 inches) in diameter, the length being 6,300 millimeters (20 feet 8 inches) in the case of the double-ended boilers, each of which has eight furnaces of 1,150 millimeters (45 inches) in diameter. The weight of the double-ended

boilers is 104 tons. The total heating surface is 8,720 square meters (93,865 square feet), the grate area being 251.16 square meters (2,702 square feet).

The boilers are arranged in four batteries, each with a funnel whose height above the fire bars is 110 feet, the diameter being 4½ meters (14 feet 9 inches). There are bunkers on each side of the boiler compartments, but the principal one is between the second and third boiler rooms, an arrangement which not only precludes the possibility of more than one-half of the boiler power being put out of action by a ship colliding at the point of connection between the bulkhead and shell-plating, but it confers the still greater advantage of enabling the central part of the ship to be given up to dining-room and other passenger accommodation.

As to the other machinery in the ship, it may be said that there are three electric generating sets, and two of Linde's refrigerating machines placed at the forward end of the shaft tunnel, with a fourth dynamo of 800 ampères well above the water line. An interesting change has been made in connection with the steering gear. As in former ships, this gear is of the Brown type; but in this case the gear has been entirely duplicated; thus, while, as formerly, there is a steering installation under the water line, the rudder post is carried right up to the poop, where duplicate engine and gear are fitted which run idle under normal conditions, but will do the work should the under-water gear become dislocated or injured. Although such gear is made of great strength, there is always the possibility of a breakdown; and it seems doubtful if handwheels, or the light emergency gear sometimes fitted, is sufficient for vessels of such high speed and great displacement.

Strength and reliability are also the characteristics of windlass and capstan gear. The forward gear consists of two cable holders, suitable for cables of 74 millimeters (2 5/16 inches) in diameter, with their brakes and coupling bosses fitted on the forecastle deck. Above the cable holders are drums for heavy warping purposes, and forward of the windlass on the forecastle deck are placed two quick-speed capstans for lighter

work, which can also be worked by hand. There are two engines of great power, with cylinders 17 inches in diameter by 13 inches stroke, and 15 inches in diameter by 12 inches stroke, each capable of doing all the work; and the wheel gearing is of cast steel and the wormwheels of gun metal. A light warping capstan is fitted forward in the bow, on the forecastle head, with engines having cylinders 11 inches in diameter by 10 inches stroke, and on the promenade deck aft are fitted three warping capstans, each driven by one independent steam engine, one having cylinders 15 inches in diameter by 12 inches stroke, and fitted with a cable wheel for working the steam cable and stern anchor; the other two engines having cylinders 11 inches in diameter by 10 inches stroke.

The vessel is 663 feet long, 66 feet beam, with a depth (molded) of 43 feet, but there are three decks above this, the total gross tonnage being about 15,000 tons and the normal displacement 21,300 tons, including 4,400 tons of coal and 5,250 tons of cargo. The total number of passengers is 1,651, including 650 first and 350 second-class passengers, while the crew number 520, including 69 deck hands, 241 in the engine-room staff, 51 in the kitchen department, with 150 stewards and 4 postal officials. In the equipment of the ship there are several interesting developments to which reference should be made as an indication of the conveniences and comfort provided for the present day travelers. In the first place there is a telephonic system, including not only the public rooms and official departments, even to the wine cellars, but also many of the private rooms; and arrangements are provided so that the ship system may be coupled up to any land trunk lines—*i. e.*, at ports of call. A messenger-boy service, with electric-call instruments, is also provided; the chief steward has an exceptionally large office, centrally situated and equipped with all the conveniences of hotel bureaus. Electric punkahs are provided in the public rooms. The electric-call bells, as well as the light switches, are arranged in the cabins so that the passenger may operate them while in bed—not a usual convenience. The ship's clocks are electrically controlled. The lookout man in the crow's nest on the foremast can ascend to his position by

a ladder inside the mast instead of outside, and there is a speaking tube down to the navigating officer's bridge.

In the matter of safety, also, the ship marks progress. Only in the bulkheads in the machinery section are there doors below the water line, and in all cases an hydraulic system is installed which is so controlled electrically that the captain on the bridge or in his cabin, or officers from various positions in the ship, may instantly close every door. To combat fire, a special pump of a capacity of 20 tons per hour is fitted, with a special system of piping throughout the ship, in which pressure is always maintained, and at many stations throughout the vessel there are special alarms, with the usual glass face; and such alarms not only communicate the fact of an outbreak to the various officers' and firemen's quarters, but also set the pump at work. These and many other ingenious details, combined with the simple yet highly artistic decoration of the public rooms, mark the *Kronprinz Wilhelm* as a great triumph in the shipbuilding art, and as testifying to the world, as the German Emperor has put it, "that the energy and enterprize of the German people never slumber, but rise from generation to generation to ever higher flights to the blessing of their Fatherland."—"Engineering."

Denver, latest addition to the Mallory Line.—This magnificent vessel, of nearly 5,000 gross tons, is a product of the shipyard of the Harlan & Hollingsworth Co., Wilmington, Del., and is the largest steamer of this class which has been launched from their yard.

The *Denver* is of the following dimensions: Length over all, 386 feet; length between perpendiculars, 368 feet; beam molded, 48 feet; depth to lower deck, molded, 16 feet; depth to main deck, molded, 26 feet; depth to awning deck, molded, 35 feet; gross tonnage, 4,549 tons; net tonnage, 2,819 tons.

The *Denver* can carry 3,000 tons deadweight on a draught of 19 feet. On this draught her speed is about 15½ knots, but on her trial trip, at sea, light, she made 16½ knots. In her spacious holds 10,000 bales of cotton can be carried. The passenger accommodations are all located amidships. The first-class passenger staterooms will accommodate sixty persons comfortably, and

there is in addition berths for seventy-eight steerage passengers. The main saloon, staterooms and dining room are all handsomely finished.

The new steamship is propelled by a direct-acting triple-expansion inverted engine, having cylinders 33, 54 and 87 inches in diameter and 54 inches stroke. The high-pressure cylinder is fitted with one piston valve, the intermediate with two piston valves and the low-pressure with a double-ported slide valve. The cylinders, cylinder heads and pistons are of cast iron, the housings, in front and back being of the same material, with the condenser attached to that at the back. Forged steel is the material used for the piston rods, connecting rods and crossheads, as well as the valve rods. Stephenson's link-motion valve gear is used. The crank shaft is larger in diameter than the classification societies require, by half an inch, and is in three interchangeable pieces. This as well as all other shafting is of forged steel.

Steam is supplied by four cylindrical boilers, each 16 feet 3 inches in diameter and 11 feet 6 inches long, and each fitted with four Morison suspension furnaces 40 inches inside diameter. The boilers are built to withstand a working pressure of 180 pounds to the square inch. Howden's hot draft is used. There is also a donkey boiler 9 feet in diameter and 9 feet 3 inches long, built for a working pressure of 180 pounds.

The hull of the *Denver* is exceedingly strong, the material used being up to or surpassing the Government and society requirements.

As the vessel has many cargo ports and deck hatches, the framing has been greatly reinforced, and in this way the entire hull is considerably stiffer than is usual in 5,000-ton ocean steamers. She has a steel flat-plate keel 36 inches wide by $\frac{18}{20}$ inch thick at the center, which is reduced to $\frac{14}{20}$ inch at ends and which is also doubled for half its length by $\frac{14}{20}$-inch plates. The best hammered scrap iron has been used in the manufacture of the stem. The bottom part is, however, of cast steel where it joins the keel plates. The stem is 11 inches by 3 inches. The stern frame is made of cast steel, as is the rudder frame. The

center continuous-plate keelson is 48 inches in depth and $\frac{14}{20}$ inch for half its length amidships, reduced to $\frac{11}{20}$ inch at ends, and extends 18 inches above top of floors. It has double angles 16½ by 4½ by $\frac{10}{20}$ inch on upper edge, the rider plates being 14 by $\frac{14}{20}$ inch, connected to floor stringers and keel plates by 6½ by 4½ by $\frac{10}{20}$-inch angles. For three-fifths the length of the center of the vessel the frames are of 7½ by 3½ by $\frac{9}{20}$-inch angles, extending in one piece from center keelson to awning-deck stringer plates, spaced 25-inch centers. There are reverse frames on every floor, being carried to the main deck. Under the engine and boilers they are double as far as the turn of the bilge.

Plates 30 by $\frac{10}{20}$ inch are used for the floors for three-fifths the length amidships, being reduced to $\frac{8}{20}$ inch at ends, and connected to the center keelson by double angles 4½ by 3½ by $\frac{9}{20}$ inch. The keelsons are all carried fore and aft, ending in efficient breast hooks that are intercostal between the floors, $\frac{9}{20}$ inch thick; extending above the floor they are secured between bulb-angles 7½ by 4½ by $\frac{10}{20}$ inch. Two hold stringers, of 15 by $\frac{10}{20}$ inch plates, connected to hull and frames by angles 3½ by 4½ by $\frac{9}{20}$ inch are on each side, and faced with 6 by 3½ by $\frac{6}{20}$ inch angles. The web frames are spaced every eight frames. The hull is divided into seven water-tight compartments by six bulkheads, each bulkhead extending to the main deck, which is of steel. The bulkheads are built of $\frac{8}{20}$ and $\frac{7}{20}$ -inch plating, stiffened by vertical angles 6 by 3½ by $\frac{10}{20}$ inch, spaced 24 inches, and by horizontal angles 8½ by 3 by $\frac{12}{20}$ inch spaced 48 inches. The bulkheads in the center of the vessel have two vertical webs at the middle line, made of 12-inch channels. All bulkheads are connected to the shell of the ship by 6 by 3½ by $\frac{10}{20}$ inch double angles. Water ballast is carried in the forward and after peaks. The plates of the bulkheads are of $\frac{7}{20}$-inch steel, having 4½ by 3½ by $\frac{9}{20}$ inch vertical stiffeners, spaced 30 inches.—"Nautical Gazette."

Bremen Reconstructed.—It will be remembered that when the great fire took place among the Hoboken docks, opposite New York, in June of last year, the burning of the North German Lloyd steamer *Bremen* was perhaps the most tragic event

of the conflagration. Not only was there a very great loss upon the steamer, but also a great loss of life as well. It was necessary to refit the ship, which at that time was only three years old, having been built by F. Schichau, in Dantzig, in 1897. It is noteworthy that in refitting the vessel it was thought desirable to considerably alter her, which has been done by lengthening her 25 feet, putting in larger boilers and new engines, such is the rapidity with which ideas regarding steamship construction now advance. The vessel recently arrived in New York on her first trip since the fire.

The *Bremen* is now 11,600 tons gross register. She has four double-ended and two single-ended boilers, carrying steam at 225 pounds pressure. In addition there is the equivalent of an additional boiler, which is a superheater. This resembles a coil boiler and is fired by furnaces. The steam passes through the coils and is superheated from 388 degrees Fahrenheit to 482 degrees Fahrenheit. The superheater was not used on the trip coming over, as it is to be tested, and the company has decided to first ascertain the coal consumption without it and afterward when using it.

There are twin screws, 5,200 millimeters (17 feet) diameter, 7,000 millimeters (23 feet) pitch. The engines are four-cylinder quadruple-expansion with four cranks, and cylinders 700 millimeters, 1,040 millimeters, 1,500 millimeters, and 2,120 millimeters (27.5, 41, 59, and 83.4 inches) diameter, 1,350 millimeters (53 inches) stroke. They are expected to develop about 8,200 horsepower; from which it will be seen that the *Bremen* is not intended for fast running, but rather to be comfortable.—"Scientific American."

Main.—The work of rebuilding the North German Lloyd Steamship Co.'s twin-screw steamer *Main*, which was partially destroyed in the Hoboken fire, in June, 1900, has been completed at the works of the Newport News Shipbuilding & Drydock Co. It required just one year to rehabilitate the *Main*, to transform a mass of bent plates, twisted stanchions, warped decks and charred woodwork into a leviathan of symmetrical lines staunch enough to weather the most furious seas. The *Main* arrived at the ship-

yard on October 13, 1900, in tow of five tugs, which brought her from New York. On October 15, the work of rebuilding the vessel from the light-water line up was begun. She was delivered to her owners on October 15, 1901.

The *Main* is again a first-class steamship. As soon as she is equipped for passenger service she will resume her place on the line between New York and Bremen. She is a fast twin-screw steamer of 10,000 gross tons, has four decks, is 501 feet long, 58.1 feet wide and 36.6 feet deep. She is fitted with electric-lighting plant, refrigerating machinery and other modern appliances. The contract for reconstructing this steamer was one of the largest ever executed by an American shipyard for a foreign company.

Siberia.—The Pacific mail steamship *Siberia* was launched at the yards of the Newport News Shipbuilding Co. October 19th. The *Siberia* and the *Korea*, her sister ship, are building for the Pacific Mail Steamship Co.'s line between San Francisco and Hong Kong. Each ship will cost, when completed, $2,000,000, and their dimensions are: Length, 572 feet 4 inches; beam, 63 feet; depth, 40 feet; draught, 27 feet; displacement, 18,600 tons. Accommodations are furnished for 200 first-class passengers and 1,200 Chinese in the steerage. The ships are designed for a sustained speed of 18 knots an hour, and it is expected that this speed will be exceeded for short periods. They are propelled by two 4-cylinder, vertical, inverted, direct-acting, quadruple-expansion engines, designed to develop 18,000 indicated horsepower at 86 revolutions a minute.

El Alba.—This steamship of the Morgan line was launched November 2 from the works of the Newport News Shipbuilding & Dry Dock Co., Newport News, Va. This makes the twelfth vessel launched at this yard for this line. *El Alba's* dimensions are: Length over all, 406 feet; length between stem and propeller post, 380 feet 8½ inches; breadth, 48 feet; depth, molded, to awning deck, 33 feet 9 inches. The engines are triple-expansion with cylinders of 33 inches, 52 inches and 84 inches diameter and 45 inches stroke. Steam is furnished by three double-ended boilers 13 feet 10 inches in diameter and 20½ feet long.

ASSOCIATION NOTES.

For the information of the Society the following communication is here published:

BERLIN NW. 6, *den September 30th, 1901.*
Schumannstr. 2, pt.

To the President of the American Society of Naval Engineers,
COMMANDER C. W. RAE, *U. S. Navy,*
Navy Department, Washington, D. C.

Dear Sir: In the name of the "Schiffbautechnische Gesellschaft" I have the honor to invite the officers and members of the "American Society of Naval Engineers," with their ladies, to our summer meeting in Düsseldorf from June the 2d to 5th next year.

You will find there an exposition promoted chiefly by the Rhenish Westfalian ironmasters, and which will include specimens of all the materials produced in Germany to-day for shipbuilding. We will do our utmost to provide a few pleasant days for you by means of a series of papers and by excursions to the great works and factories in the neighborhood. We shall make special arrangements for the ladies, while the gentlemen are engaged at the meetings, to visit the Academy of Arts, the studios of the most celebrated artists in Düsseldorf, and the silk and velvet factories in Crefeld. A final trip is planned for the whole party to the prettiest parts of the Rhine.

A special program is in preparation, and you will receive it in the first months of next year, in such a number that you can send it to all your members.

I remain, dear sir, yours sincerely,

BUSLEY,
Acting President.

A regular meeting of the Society was held at the Navy Department on October 18, 1901, for the purpose of nominating officers for the coming year. Nominations were made in writing and resulted as follows:

For President: Commander Charles W. Rae, U. S. N., and Lieutenant Commander F. H. Bailey, U. S. N.

For Secretary-Treasurer: Lieutenant Charles W. Dyson, U. S. N.

For Council (three to be selected): Commander George W. Baird, U. S. N.; Commander J. D. Ford, U. S. N.; Lieutenant Commander J. R. Edwards, U. S. N.; Lieutenant Commander W. M. Parks, U. S. N.; Lieutenant Commander F. C. Bieg, U. S. N., and Lieutenant S. E. Moses, U. S. N.

The vote will be secured by the regular voting slips and will be counted at the regular annual meeting in January.

The Secretary-Treasurer was also instructed to have prepared and forwarded to the members the regular voting slips for determining the prize essay for the current year, only one prize to be awarded.

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